BOTANICAL DIVERSITY
IN SOUTHERN AFRICA

BJ Huntley, Editor

STRELITZIA 1

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This is the first occasional publication of the National Botanical Institute to appear under the series name *Strelitzia*. The new series replaces *Memoirs of the Botanical Survey of South Africa* and *Annals of Kirstenbosch Botanic Gardens* which the NBI inherited from its predecessor organizations.

The genus *Strelitzia* occurs naturally in eastern southern Africa. It comprises three arborescent species, known as wild bananas, and two acaulescent species, known as crane flowers or bird-of-paradise flowers. The logo of the National Botanical Institute is based on the striking inflorescence of *Strelitzia reginae*, a native of the Eastern Cape and KwaZulu/Natal that has become a garden favourite worldwide. It symbolizes the commitment of the National Botanical Institute to provide the facilities, knowledge and expertise necessary to ensure the conservation, sustained use, appreciation and enjoyment of South Africa's exceptionally rich flora and vegetation.

List of species represented in the paper sculpture cover illustration by David Davidson:
Acacia karroo, Adansonia digitata, Albizia adianthifolia, Aloe dichotoma, Bartholina burmanniana, Carpobrotus quadrifidus, Citrullus lanatus, Clivia miniata, Cotyledon orbiculata, Dietes grandiflora, Disa uniflora, Erica baccans, Erica bauera, Erythrina lysistemon, Geissorhiza radians, Gladiolus saccata, Gladiolus alatus, Gloriosa superba, Heliophila coronopifolia, Huernia zebrina, Leucadendron argenteum, Leucadendron laureolum, Leucadendron salignum, Leucospermum cordifolium, Olea europaea subsp. *africana, Oncosiphon grandiflorum, Osteospermum fruticosum, Oxalis luteola, Pachypodium namaquanum, Pelargonium capitatum, Plumbago auriculata, Podocarpus latifolius, Protea cynaroides, Protea grandiceps, Senecio arenarius, Strelitzia reginae, Streptocarpus primulifolius, Thamnochortus insignis, Themeda triandra, Ursinia anthemoides, Watsonia borbonica, Welwitschia mirabilis, Zaluzianskya villosa, Zantedeschia aethiopica.*

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BOTANICAL DIVERSITY IN SOUTHERN AFRICA

Edited by
Brian J. Huntley
with the assistance of
Caroline Gelderblom and Emsie du Plessis

Proceedings of a Conference on the
Conservation and Utilization of Southern African
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National Botanical Institute
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Acknowledgements

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The administrative and logistic arrangements for the Conference were competently coordinated by Caroline Gelderblom, assisted by Karen Combrink, Diane Stafford, Yael Mirkin, Rowena Smuts and Ann Cornelissen. Caroline Gelderblom and Emsie du Plessis made a major contribution to the editorial process. Sarie Brink undertook the typesetting and David Davidson designed the cover. To these and the many other persons who contributed to the success of the project, my sincere thanks.

B.J. Huntley
Chief Executive: National Botanical Institute

Introduction: new challenges and partnerships for botany in southern Africa*

B.J. HUNTLEY
National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

THE CHALLENGE

Over 25 years have passed since the publication of *Conservation of vegetation in Africa south of the Sahara* (Hedberg & Hedberg 1968). Although important reviews on the conservation of the biodiversity of Africa have been undertaken in the intervening years (Mackinnon & Mackinnon 1986; Stuart & Adams 1990), these have been of a general nature, giving little detail on botanical resources. Even the comprehensive syntheses of Werger (1978) and White (1983) made only passing reference to botanical conservation, while most of the papers in Huntley (1989) are restricted in their cover to South Africa. In order to redress this situation, a Conference was convened in Cape Town, South Africa, in September 1993. The Conference was convened by the National Botanical Institute, as a contribution to the IUBS/SCOPE/UNESCO *Diversitas* programme, which seeks to describe and explain the origin, function and status of biodiversity around the world (Di Castri & Younes 1994).

The Conference comprised a Symposium of invited review papers and a Workshop which analysed the key issues relevant to the conservation and utilization of southern Africa's botanical diversity. The overall objectives of the Conference were:

- To assess the conservation status of the indigenous botanical resources of southern Africa by identifying centres of high floristic diversity, threatened plant species and communities, and plant species or communities of high economic value.

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* In this volume, southern Africa is defined to include Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe. It therefore includes both the *Flora of southern Africa* and the *Flora zambesiaca* geographic entities. Much of the information used in recent floristic analyses has been based on the *Flora of southern Africa* grouping of Botswana, Lesotho, Namibia, South Africa and Swaziland, for which the PRECIS database (Arnold & De Wet 1993) provides a wide range of statistics. The frequently quoted figure of 22 000 species of flowering plants occurring in South Africa or southern Africa is misleading—the figure includes not only the flora of five countries, but also bryophytes, pteridophytes, gymnosperms and amongst the angiosperms, several hundred naturalized aliens.

TABLE 1.—Resource statistics for southern African countries. Data are for 1990 or the period 1987–1990. Socioeconomic data have been taken from *World resources 1992/93*, published by World Resources Institute, Washington. Biodiversity indicators from Stuart & Adams (1990).

	Angola	Botswana	Lesotho	Malawi	Mozambique	Namibia	South Africa	Swaziland	Zambia	Zimbabwe	Total
Basic economic indicators											
Gross National Product 1989											
Total, million US $	6 010	1 105	816	1 475	1 193	1 540	86 029	683	3 060	6 076	107 987
Per capita, US $	620	940	470	180	80	1 245	2 460	900	390	640	–
Official Development Assistance											
Average annual, million US $	163	155	144	349	847	33	0	38	433	278	2 440
As % of GNP	3	9	16	26	74	2	0	6	14	5	–
Per capita, US $	16	131	74	48	53	34	0	31	50	28	–
External debt											
Total debt 1989, million US $	n/a	513	324	1 394	4 737	n/a	n/a	281	6 873	3 088	–
Population & human development											
Size and growth of population											
Population, millions, 1990	10.2	1.3	1.8	8.7	15.7	1.8	35.3	0.8	8.5	9.7	93.8
Population change, annual average %	2.7	3.7	2.8	3.5	2.6	3.2	2.2	3.7	3.8	3.2	–
Life expectancy, years	46	61	58	49	48	59	63	55	55	61	–
Child deaths < 5 yrs per 1000 live births	214	78	119	239	219	159	80	155	113	99	–
Access to safe drinking water, urban %	75	70	59	66	44	n/a	n/a	100	76	95	–
rural %	19	n/a	45	49	17	n/a	n/a	7	43	80	–
Adult female literacy % 1990	29	65	n/a	n/a	21	n/a	n/a	n/a	65	60	–
Land cover and settlements											
Land area, million hectares	124.7	56.7	3.0	9.4	78.4	83.3	122.1	1.7	74.3	38.7	592.3
Per cent of land area arid or semi-arid	12	100	28	0	17	99	68	22	2	49	–
Population density per 1000 ha	80	23	585	930	200	22	289	458	114	251	–
Urban population as % of total	28	27	20	12	27	28	60	33	50	28	–
Food and agriculture											
Cereal production, average, 1000 tonnes	302	79	177	1498	634	135	12 784	146	1 742	2 679	20 176
Yield of cereals, average, kg/ha/yr	307	331	765	1 107	551	591	1 953	1 833	1 818	1 539	–
Livestock populations											
Cattle (1 000)	3 133	2 522	530	987	1 367	2 061	11 857	654	2 772	6 252	32 135
Sheep and goats (1 000)	1 250	2 176	2 500	1 107	500	9 079	36 914	356	606	3 146	57 634
Wildlife and habitat											
Protected areas (1 000 ha)	2 692	10 025	7	1 067	?	10 346	6 310	40	6 361	2 831	–
Energy and materials											
Commercial energy production, petajoules	959	19	0	2	1	0	3 875	6	34	159	5 055
Freshwater resources											
Renewable water resource, km^3	158	1	4	9	58	9	50	7	96	23	415
Biodiversity indicators											
Mammals	275	154	54	187	205	190	283	46	228	194	
Birds	872	569	288	630	666	640	774	477	732	635	
Freshwater fish	268	81	8	600	–	97	220	45	156	132	
Vascular plants	5 000	2 000	1 700	3 600	5 500	3 159	20 300	3 000	4 600	4 200	

- To evaluate the databases, expertise, infrastructure and educational facilities available for the further study, conservation and sustainable utilization of botanical resources.

- To develop realistic and achievable goals and priorities for a regional strategy, and to prepare phased action plans and partnerships to implement the strategy.

The Conference succeeded in meeting some of its objectives, the results of which are reflected in this volume. It was adequately clear, however, that the Conference provided but one link in a chain of activities that need to be undertaken to consolidate existing botanical expertise in the region and to build the local, indigenous, intellectual capacity needed to meet the demands of the 21st century. The conclusions and recommendations arising from the Workshop provide a framework for continued consultation, partnership and action across the subcontinent, made possible for the first time through the dramatic and positive sociopolitical changes witnessed in South Africa during 1994.

The vast disparities between the different countries of the subcontinent (Table 1) reflect both the history and inherent natural resource base of the region. Deforestation, overgrazing, soil erosion and species loss are endemic, and are symptoms of more profound socioeconomic ills. Despite the magnitude of ecosystem collapse in southern Africa, botanists have had limited success in influencing resource management policy and practice. Planners, bankers and politicians dominate the decision-taking arenas. The role of botany, and of botanists, can and must change dramatically. The indigenous botanical resources and knowledge base must be mobilized to contribute to the environmental upliftment and improved quality of life of all communities. This can only happen, however, if the complacency and in many cases, despondency, of botanists in the region changes to positive actions leading to an assertive and independent core of professionals. For too long, botanists in the region have either abdicated responsibilities to their colleagues in former colonial institutions, or to the wave of expatriate researchers visiting Africa as scientific ecotourists. It is time for southern African botanists to take charge of their futures, just as their colleagues in socioeconomic and political spheres have done. The review papers and workshop reports in this volume indicate that the goal of a strong network of plant scientists can be achieved in southern Africa. Independence does not imply isolation. Southern African botanists will continue to benefit from partnerships with colleagues throughout the world, most particularly those in Kew, Missouri, Uppsala, Paris, Berlin and Lisbon.

The challenge of developing a new botanical agenda for southern Africa is not insurmountable, nor is the concept of such an initiative naive or premature. With few exceptions, all southern African countries possess small but committed nuclei of young botanists in their universities and research institutes. Support from aid agencies has allowed many of these students to obtain training in Europe or North America. Increased government interest in environmental issues and the new demands placed on governments by the international community to undertake

environmental impact assessments, biodiversity evaluations and natural resource inventories increase the employment opportunities for African botanists. But the potential of establishing a really meaningful network of southern African botanists has, for many decades, been frustrated by several factors:

- The exclusion, for well-founded political reasons, of South Africa from any regional initiative—the 'political impediment'.
- The absence of adequate Africa-based education and training facilities in botany, with the consequence that the few Africans wishing to pursue careers in botany have had to travel to institutions on other continents, with totally unfamiliar floras and ecosystems.
- The absence of career opportunities in systematics and the poor financial support for herbaria, resulting in the 'taxonomic impediment'—the almost complete suspension of Africa-based taxonomic studies since the end of the colonial era.
- The absence of a 'critical mass' of botanists within any one institution, even within a single country, to generate the energy and momentum needed to initiate and sustain a regional network.
- The self-effacing and inherently passive personalities of most botanists.

The removal of the political impediment' through the transition to a democratic government in South Africa opens the door to new and exciting possibilities. Most of the other obstacles to developing a vibrant network of botanists can now fall away. The enthusiasm and common vision displayed by the 130 botanists from all southern African countries who participated in the Conference suggests that a truly meaningful network will rapidly emerge. The goals and activities of such a network are described in the workshop reports published together with the conference papers in this volume.

CONFERENCE PAPERS

The conference papers cover a wide spectrum of botanical issues, techniques and priority needs. In his opening address to the Conference, Colin Cameron draws specific attention to the benefits to be enjoyed throughout southern Africa through the sharing of expertise, facilities and experience. He further emphasizes the need for high-quality research, not only in the pursuit and dissemination of knowledge, but as importantly, for rational decision making. The origins of modern botanical research in southern Africa are described by Bertil Nordenstam, in his keynote address on the life of Carl Peter Thunberg, celebrating the 250th anniversary of the Swedish botanist's birth. Aptly named the father of South African botany, Thunberg provided the original descriptions of 719 species from South Africa, no less than 317 names of which are still upheld (Rourke, pers. comm.).

The nature of botanical diversity in southern Africa, in terms of patterns of species richness and endemism, is reviewed by Richard Cowling and Craig Hilton-Taylor. They identify six 'hot-spots' of floristic diversity in southern Africa and describe the Cape Floristic Region as the hottest hot-spot of floristic diversity in the world, in terms of levels of species richness, endemism and threat.

Country-specific analyses of botanical diversity and its conservation are presented for six of the region's ten countries. Brian Huntley and Elizabeth Matos describe the rich phytochorological and ecological diversity of Angola, a country of immense biological interest which has been abandoned by botanical researchers for nearly 20 years due to the continuing civil war. Although most of the larger mammals, birds and reptiles in the war-torn country have been killed for food or sale, the vegetation has been largely unaffected by the war, and in many areas forests are recovering from previous overexploitation. The flora of the mountain kingdom of Lesotho, under pressure from intense overgrazing and the impact of the Lesotho Highlands Water Project, is described by Sumitra Talukdar. Gillian Maggs and co-authors use distributional data on 3 540 species and 150 endemic or near-endemic species to identify centres of botanical importance in Namibia, the first objective analysis of its kind from this large arid country.

Mozambique, like Angola, has been subject to extended civil war since 1975, with the consequent disruption of botanical research and conservation activities. Salomao Bandeira and colleagues describe the major vegetation types and their distribution in relation to protected areas and provide a preliminary listing of threatened plants of Mozambique. Kate Braun reviews the history of botanical collection in Swaziland and provides an analysis of the country's flora compared to other similar-sized countries around the globe. She demonstrates Swaziland's relatively high species richness but very low levels of endemism, as might be expected in a small land-locked country.

In common with most African countries, the design and distribution of protected areas in Zimbabwe was determined primarily in relation to large mammal populations. Jonathan Timberlake and Thomas Müller present an hierarchical approach to identifying botanical conservation priorities for Zimbabwe.

Five papers examine various aspects of the human dimensions of botanical diversity conservation and utilization in southern Africa. Joseph Matowanyika examines the relationship between biodiversity conservation and human populations. He stresses the important and sensitive interface between rural communities and the species of animals and plants that conservationists wish to protect. Such rural populations are recipients of both the benefits and the costs of maintaining biodiversity and their participation in decision making around policy and action is essential for the long-term success of any conservation strategies. Tony Cunningham uses evidence from Africa, Australia and the Americas to demonstrate the value of partnerships and cross-pollination between resource users, managers and researchers of botanical diversity. The traditional or customary knowledge of rural people is an invaluable resource, and an urgent need exists for the development of cross-cultural communication systems to promote

the sharing of knowledge in participatory research projects. The results of one such project, on medicinal plant use in Zimbabwe, is described by Steve Mavi. Mavi and his co-workers found that 500 species, or 10% of the flora, are known to be used in traditional medicine.

Human resources in southern Africa are assessed by Snowy Baijnath and Ashley Nicholas in terms of herbarium infrastructure and staffing. Compared with Europe, North America and Australia, southern Africa is very poorly supplied with the herbarium facilities and human skills needed to address environmental problems in the region. Baijnath and Nicholas make a strong case for developing a southern African network of plant taxonomists. This sentiment is echoed in the analysis of tertiary education and training facilities for botany in southern Africa undertaken by Danny and Jay Walmsley and Avi Anati. They conclude that there is no absolute shortage of educational and training facilities in the region, but that these resources are unequally distributed, with the vast majority being centred in South Africa, while some countries such as Angola and Mozambique remain very inadequately served.

Measures of diversity and approaches to identifying sites of conservation priority are described in three papers. Peter Linder proposes an index of biodiversity in which taxonomic diversity is deweighted by measures of functional diversity, in this way reducing the influence of a few very specious genera (such as *Erica*) in the measurement of biological diversity. In the only conference paper dealing at the intraspecific or genetic level, Nigel Barker and co-authors describe the use of a DNA-based finger-printing technique to measure the genetic variation between five populations of *Prunus africana*, an Afromontane forest tree which is threatened by overexploitation for the pharmaceutical industry. Moving from the genetic to the ecosystem level, a detailed description of an iterative approach to selecting centres of endemism and species richness is presented by Tony Rebelo. Rebelo uses the PRECIS computerized floristic database developed at the National Herbarium, Pretoria, to select the optimal design of protected areas for five of southern Africa's ten countries (Botswana, Lesotho, Namibia, South Africa and Swaziland). At a much finer scale, he tests the existing network of protected areas in the Cape Floristic Region with detailed information gathered for the Proteaceae.

A series of case studies is presented to provide focus on different threats, processes, taxonomic groups and actions taken to respond to the biodiversity crisis. Julia Wood and co-authors describe the dramatic loss of species and habitat that has occurred during the past three centuries in the western Cape, resulting in the highest concentration of threatened species reported anywhere in the world. David Everard, Gideon van Wyk and Jeremy Midgley use evidence from forests in Natal to argue that moderate levels of disturbance are essential to the maintenance of diversity in these ecosystems. They suggest that carefully managed utilization regimes are compatible with biodiversity conservation and with satisfying the needs of rural communities.

The conservation of taxa that have become popular in the horticultural trade has in the past been approached through the preparation and monitoring of *Red data* lists and the implementation of appropriate legislation. These approaches are comprehensively reviewed by Craig Hilton-Taylor and Gideon Smith in a case study of the 233 species of the Aloaceae occurring in the *Flora of southern Africa* region. They find that 31% of the southern African Aloaceae are threatened to some degree, with particularly high levels of threat in *Aloe* and *Haworthia*.

Botanical gardens have experienced mixed fortunes in postcolonial Africa, with several important living collections having been lost over the past few decades. An exemplary case study of what can be done to rehabilitate a garden that has fallen on hard times is presented by Nouhou Ndam, with reference to the Limbe Botanic Garden, Cameroon. Although the case study comes from outside of the geographic region covered in this volume, it provides a model that might well be emulated by countries in the subcontinent.

The conference papers are concluded with three contributions on international and regional initiatives. Steven Njuguna describes the Convention on Biological Diversity and its implementation needs in Africa. The Convention can provide a useful vehicle for regional cooperation and the stimulation of action by politicians as well as by the public. A similar global initiative with local actions is the TRAFFIC network, described by David Newton and Ashish Bodasing. Although much of the European and North American horticultural industry is based on southern African plant genetic resources, few quantitative data exist on the continuing legal and illegal trade in this flora. More sophisticated and effective controls on the exploitation of southern Africa's plant genetic resources are recommended by Helen Moss, in the final conference paper which describes innovative approaches to ensuring that the benefits of this resource accrue to southern African rather than foreign countries.

WORKSHOP CONCLUSIONS

The three-day Workshop which followed the Symposium drew together 80 plant scientists and conservationists from 14 countries, including active botanists from all ten southern African countries. The Workshop examined ten key issues relevant to southern African botanical resources. Although the ten working groups met in plenary sessions at regular intervals, most of the time was spent in independent work sessions. What was remarkable was the unanimity of the principal conclusions of each group, presented in the workshop reports in this volume, which can be summarized as follows:

- Southern Africa has an extremely rich, but in some areas poorly researched botanical diversity.
- Most countries in the region have very few trained botanists in permanent posts, few have more than rudimentary facilities.

- As a whole, however, southern Africa possesses the human resource potential in biology to make a meaningful contribution to the study, conservation and use of its botanical diversity.
- This potential could be best developed and strengthened through the formation of a regional network of botanists.
- A mechanism must be established, with appropriate funding, to ensure that the urgent capacity building and infrastructural support needed to mobilize the region's latent potential is realized.

While various formal mechanisms (such as the Southern African Development Community) and scientific associates (such as AETFAT) exist which can provide a structure for the creation of a network of southern African botanists, it is clear that unless individual workers commit themselves to a regional programme of partnership and capacity building, the ambitious proposals of the Workshop will come to nothing. Fortunately, the upsurge of regional collaboration following the establishment of a democratic government in South Africa promises an exciting and productive future.

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Opening address

C.M. CAMERON

Director General, Department of Environment Affairs, Private Bag X447, Pretoria, 0001 South Africa.

> 'And the Lord God planted a garden in Eden in the East where He put the man whom He had formed. And out of the ground the Lord God made to grow every tree that is pleasant to the sight and good for food........'
> (*Genesis* 2: 8 and 9)

Mr Chairman, honoured guests, visitors from abroad and elsewhere in Africa, ladies and gentlemen:

One rarely has the privilege of opening an international congress. For this honour I am greatly indebted to the organizers of this Conference on the conservation and utilization of southern Africa's botanical diversity.

Many topics were discussed at the United Nations Conference on Environment and Development (UNCED) that was held in Rio de Janeiro during June 1992—but only two of these eventually resulted in the formulation and acceptance of specific conventions, namely:

- the Framework Convention on Global Warming, and
- the Convention on Biological Diversity.

One is prompted to ask why, amidst the full spectrum of themes that are addressed in Agenda 21, were these two topics selected for specific attention. There may be numerous reasons, but I would suggest that the consequences of global warming and the loss of biodiversity fundamentally affect the very survival of mankind on our planet.

In Article 2 of the Convention on Biological Diversity, biodiversity is defined as follows:

Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and diversity of ecosystems.

The *significance* of biodiversity is well described in the introduction of the *Global Biodiversity Strategy*. It states:

'*In the remote past, human actions were trivial when set against the dominant processes of nature. No longer. The human species now influences the fundamental processes of the planet. Ozone depletion, worldwide pollution, and climate change are testimonies to our power.*

'*Economic development is essential if the millions of people who live in poverty and endure hunger and hopelessness are to achieve a quality of life commensurate with the most basic of human rights. Economic progress is urgent if we are not only to meet the needs of the people alive today, but also to give hope to the billions born into the world over the next century.*'

'*The conservation of biodiversity is fundamental to the success of the development process. It is* not *just a matter of protecting wildlife in natural reserves. It is* also *about safeguarding the natural systems of the earth that are our life-support systems and the genetic richness on which we depend in the ceaseless struggle to improve our crops and livestock*' (abbreviated).

'*Saving biodiversity means taking steps to protect genes, species, habitats, and ecosystems. The best way to maintain species is to maintain their habitats. Saving biodiversity therefore often involves efforts to prevent the degradation of key natural ecosystems and to manage and protect them effectively. But since many of the world's habitats have been modified for such human uses as agriculture, the program must include measures to maintain diversity on lands and in waters that have already been disturbed. A third component is restoring lost species to their former habitats and preserving species in gene banks, zoos, botanic gardens, and other off-site facilities.*'

This Conference is in effect a pre-emptive and timeous response to certain objectives embodied in the Convention on Biological Diversity. Moreover, it is also in accordance with a previous world environmental credo, namely 'Think globally; act locally'—in which case 'locally' should not be interpreted in the restricted sense, but appropriately in the southern African regional context. The Department of Environment Affairs is indeed proud to have contributed to and be associated with this splendid effort and other established programmes and endeavours such as the Heritage Programme.

With regard to the Convention on Biological Diversity there are two areas of advantage for South African participation, *as well as* for countries elsewhere in Africa.

South Africa will benefit through:

- a formal mechanism for *collaboration* with its neighbours in all aspects of biodiversity conservation;

- the opportunity to *learn* from the experience of other countries, such as Zambia and Botswana, in the development and implementation of National Conservation Strategies;
- the potential of *joining* the network of Southern African Regional Plant Genetic Resources projects, based in Zambia and already well advanced as a regional cooperative venture;
- *sharing* of expertise and technologies developed in Zimbabwe with regard to environmental education and awareness, and
- closer *linkage* with IUCN and other conservation bodies active in southern Africa.

Similarly, South Africa can *share* its experience and expertise with other southern African countries in the fields of:

- *identification, evaluation and inventory of centres of diversity*—especially through computer-based information systems such as the PRECIS data base in Pretoria;
- *support* for protected area *rehabilitation projects*, such as are needed in Angola and Mozambique, through reintroduction of wildlife populations;
- support for the development of *botanical gardens*, especially technical advice on the growing and display of the indigenous plants of southern Africa;
- *interactions* with *universities and training centres*, through the possible exchange of lecturers and students, and finally
- *exchange of information* and in particular, publications from our many conservation departments and research groups, particularly those in our museums and herbaria.

This Conference and its supporting activities fulfil the requirements of a comprehensive strategy towards realizing the above-mentioned common benefits—namely analysis, assessment and action.

- During the symposium an analysis of the problems will be done by *sharing of expertise*;
- in the *workshops* an *assessment* of the current situation will be made by *intensive study*, and
- the *training courses* will lead to *action* through *capacity building*.

Indeed a well planned approach that is designed to guarantee success, inspire dedication and promote the conservation of biological diversity.

Although this Conference focuses on the floristic kingdom, we must not be restricted in our thinking about biodiversity. We must not forget that the microbes that occur in the air, soil and water, the great mammals that stride the earth, the insects that complete the food chain, the birds of the air and all marine life, are also part of the world's wondrous diversity.

All the events of this Conference are directed at the pursuit and dissemination of knowledge. Existing knowledge emanates from study and new knowledge is generated by research.

- If we neglect research, we erode our knowledge base;
- if we erode our knowledge base, we compromise rational decision making;
- if we compromise decision making, we jeopardize civilization and our future.

And apart from the primary role of research, it also ensures that there are competent people who are able to receive new technology and apply it locally.

The speedy establishment of adequate research facilities is therefore imperative.

But ladies and gentlemen, in these times of political and social upheaval where poverty and despondency are rampant, we dare not study botany merely for the sake of scientific curiosity or personal satisfaction. Our endeavours must be directed at and transposed into useful results for the benefit of all the people that live in this region.

As I have stated elsewhere: 'Unless we address environmental issues in terms of human wellbeing, we neither understand our calling, nor has our custody of creation any meaning.'

But what benefit does the study of botany and biodiversity hold? May I mention a few.

- ***More effective food production***

As a result of advanced plant breeding techniques, most food plants are extremely homogeneous, genetic diversity has been lost, and they are consequently very vulnerable.

Of all the potential advantages resulting from the conservation of biodiversity, the agricultural benefits are probably the greatest.

In this regard I cannot improve on the foreword to the *Global Biodiversity Strategy*:

'*Loss of genetic diversity could imperil agriculture. How much of the genetic base has already eroded is hard to say, but since the 1950s, the spread of modern 'Green Revolution' varieties of corn, wheat, rice, and other crops has rapidly squeezed out native land races. Modern varieties were adopted on 40% of Asia's rice farms within 15 years of their release, and in the Philippines, Indonesia, and some other countries, more than 80% of all farmers now plant the new varieties. In Indonesia, 1 500 local rice varieties have become extinct in the last 15 years. A recent survey of sites in Kenya with wild coffee relatives found that the coffee*

plants in two of the sites had disappeared, three sites were highly threatened, and six were possibly threatened. Only two were secure.

'*The impact of such losses of genetic diversity often registers swiftly. In 1991, the genetic similarity of Brazil's orange trees opened the way for the worst outbreak of citrus canker recorded in the country. In 1970, US farmers lost $1 billion to a disease that swept through uniformly susceptible corn varieties. Similarly, the Irish potato famine in 1846, the loss of a large portion of the Soviet wheat crop in 1972, and the citrus canker outbreak in Florida in 1984 all stemmed from reductions in genetic diversity.*

'*The continued existence of wild and primitive varieties of the world's crop plants is humanity's chief insurance against their destruction by the equivalents for those crops of chestnut blight and Dutch elm disease. This is not a remote eventuality. It happened once with the European grape vine. In the 1860s* Phylloxera, *an insect which lives on the roots of the vine, arrived in Europe from North America. Its effect was catastrophic. Almost every vineyard on the continent was destroyed. Then it was discovered that the native American vine is tolerant of* Phylloxera. *Europe's wine production was saved only by the grafting of European vines onto American rootstocks—a practice that continues today.*

'*The prospects of similar disasters striking other crops increase as farmers rely on fewer varieties. Because of intensive selection for high performance and uniformity, the genetic base of much modern food production has grown dangerously narrow. Only four varieties of wheat produce 75% of the crop grown on the Canadian prairies; and more than half the prairie wheatlands are devoted to a single variety (Neepawa). Similarly, 72% of US potato production depends on only four varieties, and just two varieties supply US pea production. Almost every coffee tree in Brazil descends from a single plant, and the entire US soybean industry is derived from a mere six plants from one place in Asia.*'

We need to rectify the situation by reintroducing desirable genetic traits into our crop plants and focus on creating plants that:

- will give higher yields
- are easier to harvest
- are drought-resistant
- are disease- and pest-resistant
- have a higher nutritional value
- maintain their quality after harvesting, and
- are easier to pack and transport.

By using genetic engineering and biotechnology techniques, it is now possible to produce rapidly new hybrids and transgenic plants. The critical prerequisite is, however, that the genetic diversity and the gene base must be conserved.

We must, however, appreciate that feeding the world is not primarily a technical problem—it is an economic one.

Nevertheless, ... 'over time, the greatest value of the variety of life may be found in the opportunities it provides humanity for adapting to local and global change'.

- ***Medicinal uses***

Many of our existing therapeutic substances, for example antibiotics and cardiac glycosides, have their origin in unique chemicals produced by microbes and plants. The search for new substances continues and the revived interest in ethnobotany is commendable. Will the plants of southern Africa possibly provide chemotherapeutic substances for the mitigation of AIDS and malignancies?

- ***Energy***

Although the world's major energy source, particularly for industrial purposes, is the combustion of fossil fuels, the majority of people are still dependent on wood as an energy source for heating and cooking. Planting trees for fuel wood should therefore receive our energetic support.

- ***Combating weeds and invaders***

Vast tracts of productive agricultural land have already been rendered useless through the invasion of alien and indigenous plants. Mechanical clearing and the application of herbicides have only given limited and temporary results and the only prospect of curtailing and reversing this trend is by biological control. We should not relent in our endeavours to find effective control measures by studying plants and their natural parasites.

- ***Commercial value***

Southern Africa has a great diversity of plant and animal communities, reflecting the wide range of environmental conditions in the region. The region is particularly rich in plant species. The flora comprises some 20 300 species, more than the total number found in North America and about 8.4% of the world's total. About 80% of these species are endemic to southern Africa. The Cape Peninsula alone, which is only 47 000 ha in extent, has 2 256 indigenous plant species. Species richness in other taxonomic groups is also high, although it does not match that of plants.

One of the most outstanding features of the biodiversity of South Africa is the richness of plant species in the Fynbos Biome. Some 8 504 species of flowering plants and gymnosperms and about 75 species of ferns and nonflowering vascular plants occur in the Fynbos Biome. They make up 45% of the plant species found in southern Africa. The fynbos also boasts a high degree of endemism: nearly 70% of species and 20% of plant genera are endemic.

This brings me to a very important point, namely, how can we benefit from the commercial utilization of our indigenous plant riches?

Our horticultural industry, excluding cutflowers, bulb, rose and protea exports, is valued at approximately R390 million wholesale annual turnover. It is estimated that our ornamental plant turnover is approximately R42 million. Approximately 20% of this would be indigenous plant sales locally, i.e. R8.4 million. Twenty-five per cent of the ornamental varieties available are *indigenous*, and they can account for as much as 40% of sales. The horticultural industry can in fact profitably expand. It is also a major employer of labour.

Regrettably many of our indigenous plants have been taken overseas and hybridized and are now being reimported. These include gazanias, agapanthus, pelargoniums, gladioli and watsonias.

The benefits of our indigenous plants are that they are conditioned to our climate and can withstand our drought and poor soil conditions.

We need to protect our indigenous plant material with trade marks, royalties and plant breeders' rights, because if we do not, the overseas nurserymen will do so, to their benefit.

- ***Aesthetic and spiritual value***

In an era where virtually everything is reduced to monetary assessment, we must guard against the erosion of spiritual and aesthetic values. The science of botany and the practice of horticulture must also be pursued for its primary sheer beauty. Contemporary humanity has a need, not only to survive but also to enjoy a meaningful life. There is a necessity to renew and forge a unity with nature, particularly in many deprived and disadvantaged communities. The beauty of plants can indeed be the vital element in this regard. To quote Farieda Khan: we must reincalcate the relationship of people with their natural environment.

Ladies and gentlemen—plants, like humans, are destined for functional eternity.

In *Revelations* 2: 2 we read:

> '...... and on each side of the river stood the tree of life with its twelve kinds of fruit yielding its fruit each month *and the leaves of the tree were for the healing of the nations.*'

May we pray that the healing value of the tree of life will now manifest itself in a disrupted and distorted world and bring tranquility and peace.

Now that the shackles of political bondage have been shed, we can enter an era of mutual endeavour.

With the exception of the Cape flora, most of southern Africa's biodiversity is shared between all the countries of the subcontinent. Research and information on the elephant, ostrich or baobab are of importance throughout the region and must be effectively shared. The botanical collections in the herbaria of Maputo,

Harare, Lusaka, Huambo, Zomba, Pretoria, etc. all hold material that can best be utilized if there is free and active exchange between these centres. We look forward to developing informal links with our colleagues through the conference, and at an appropriate time, formal intergovernmental links and joint projects.

As much as South African botanists have suffered from not being able to see the 'big picture' of southern African vegetation, such as the miombo woodlands of Zambia, Angola, Malawi, etc., so too have our colleagues north of the Limpopo been poorer for not being able to get to know the Cape Floristic Kingdom. We hope that their present visit will whet their appetites for further contact.

This Conference must be far more than only a scientific event—it must also be a symbol of cooperation, understanding, peace and hope.

May we all leave here inspired and with renewed dedication to our calling.

It now gives me singular pleasure in formally declaring this Conference opened.

I thank you for your attention.

Keynote address: Carl Peter Thunberg (1743–1828), the father of South African botany

B. NORDENSTAM
Swedish Museum of Natural History, P.O. Box 50007, S-104 05 Stockholm, Sweden.

Figure 1.—Carl Peter Thunberg as a middle-aged man.

Linnaeus, the greatest Swedish scientist of all time, did not travel outside Europe, but we know that he had a strong desire to go to South Africa. He later regretted that he in 1735 had declined an offer by Boerhaave in Leiden to go to the Cape and to America for a period of three years. But, as we all know, Linnaeus instead sent out his disciples on long journeys of exploration to known and unknown parts of the world, and we also know that many of them suffered from hardships of travel and tropical diseases and died in foreign countries. Carl Peter Thunberg (Figure 1) became the most successful of all these Linnaean apostles; he survived a nine-year journey to distant countries and held the Linnaean chair at the University of Uppsala for 44 years (Gunn & Codd 1981; Karsten 1939–1946; Nordenstam 1977, 1993).

THUNBERG'S LIFE AND TRAVELS

Carl Peter Thunberg was born on 11 November 1743 in the town of Jönköping in Småland, southern Sweden. His father, who was a tradesman and bookkeeper, died when Carl Peter was seven years old. The thrifty widow, whose name was Margaretha (née Starkman), continued the business, was remarried to another trader by the name of Gabriel Forsberg, and managed to provide a decent upbringing for her two sons. Carl Peter was meant to go into merchandise after a minimum of school attendance, but his talents for studies were soon discovered. He passed all grades of the elementary school and in 1761 enrolled at the University of Uppsala. He stayed there for nine years, studying the compulsory courses in theology, public law and philosophy, whereafter he specialized in chemistry and medicine (Nordenstam 1993).

Linnaeus, who besides his other duties was inspector for the students from the province of Småland, soon took notice of the conscientious young student with an aptitude for medicine and natural history. In 1767 Thunberg *pro exercitio* defended a medical thesis (*De venis resorbentibus*) under Linnaeus and took his academic degrees in rapid succession. In 1770 he graduated as a licentiate and in the same year defended a medical dissertation on sciatica (*De ischiade*) under the medical professor Sidrén.

Linnaeus was also instrumental in providing Thunberg with a small travel grant for studies abroad. The destination was Paris, the medical centre of the world. Thunberg travelled by sea via Copenhagen to Amsterdam, where he visited Johannes and Nicolaas Laurens Burman, father and son, and both friends of Linnaeus. Thunberg was cordially welcomed and developed a close friendship with the younger Burman, who was ten years his senior, and his family.

During his stay in Holland, Thunberg also visited Leiden where he met with David van Royen and Jan Frederik Gronovius, both well known in natural history, especially botany, and correspondents of Linnaeus.

The Burmans were impressed with Thunberg's knowledge of natural history and suggested that he should go with a Dutch East Indiaman to some exotic destination. Thunberg consented gladly, but had to go through with the planned studies in Paris, where he spent almost a year. In the meantime the destination had become defined as Japan, the plants of which were practically unknown in the Western world and believed to be suitable for European gardens.

Gardening was fashionable in Holland at the time and exotic plants were much in demand. It was easy to find sponsors for the project, and three patrons were especially helpful. They were Jan van der Poll, Daniel ten Hove and Daniel Deutz, and all were later commemorated in genera described by Thunberg. *Pollia*, *Hovenia* and *Deutzia* are all known in horticulture and especially the deutzias are garden favourites with a large number of species, hybrids and cultivars.

In 1635 Japan was closed to the Western world except Holland and China, and in Thunberg's days only Dutch ships were allowed to visit, with two vessels a year, and they were confined to a small islet in the harbour of Nagasaki. Thunberg had to pass as a Dutchman, and for this purpose it was decided that he should spend some years at the Dutch Colony at the Cape, to learn the language, but also to explore the flora.

Thunberg was employed as extra surgeon on the East Indiaman 'Schoonzigt' which happened to be commanded by a Swedish captain by the name of Rondecrantz. Around New Year 1772 they sailed from Holland in a convoy of four ships. The voyage lasted three and a half months, and 115 men on board the Schoonzigt died on the way. It was quite normal to lose at least one third of the crew, soldiers and sailors who were to a large extent recruited by dubious methods and in poor health.

Thunberg and the officers were also poisoned on board, when the cook had by mistake mixed white lead in the pancakes. Nobody died from this mishap, but Thunberg was very sick, having eaten one of the last pancakes, rich in lead. Although Thunberg eventually recovered from the poisoning, he afterwards suffered from stomach troubles all his life. Characteristically, Thunberg recorded the effects and after-effects of the poisoning in detail in an article published by the Swedish Academy of Sciences—his first scientific publication (Thunberg 1773).

On 16 April 1772 the ship anchored in Table Bay, and on the following day Thunberg could go ashore. By coincidence his compatriot and friend Anders Sparrman arrived simultaneously on board a Swedish East Indiaman. They spent some time together at the Cape, but they soon parted, Sparrman going with Captain Cook on his second voyage to the South Seas. When Sparrman returned three years later to explore the Cape (Forbes 1965, 1975–1977), Thunberg had already departed and was on his way to Java and Japan.

Thunberg spent the winter at the Cape, getting acquainted with Cape Town, its immediate surroundings and its flora. His collections are still well preserved in the Botanical Museum in Uppsala, with many duplicates in the Swedish Museum of Natural History in Stockholm and in several other herbaria.

The settlement of Cape Town was still rather modest, with small thatched stone-houses in square blocks, the most conspicuous features being the citadel, the church, and the Company's garden, which supplied fruit and vegetables to the seafarers. The Cape of Good Hope was sometimes regarded as the southernmost point of Africa. The maps available to Thunberg were generally poor and rather fanciful.

The white minority's servants were slaves, who were recruited mainly from Madagascar for the Company and from India for private households. Hottentots were still frequent in the Colony, but less often used as servants in the town, more often in the countryside and on travels.

Thunberg was soon familiar with Table Mountain, which he climbed altogether 15 times. In June he also made a longer excursion to the wine districts at Paarl, where French Huguenots had planted vineyards already in the 17th century. When springtime approached, Thunberg prepared for his first long expedition in the Colony. Travelling was done by ox carts and on horseback. Thunberg's equipment was meagre due to his constantly poor financial position, but since the journey was undertaken at the Company's expense, he could provide himself with 'necessary clothes, as well as with boxes and bags, for collecting bulbs and seeds, with boxes and pins for insects, a keg of arrack for preserving serpents and amphibious animals, cotton and boxes for stuffing and keeping birds in, cartridge-paper for the drying of plants, tea and biscuits for my own use, and tobacco to distribute among the Hottentots, together with firearms, and a large quantity of powder, ball, and shot of various kinds.'

Thunberg's travel companions were the gardener Johann Andreas Auge who was superintendent at the Company's garden, a young lieutenant Daniel Ferdinand Immelman, a sergeant Leonhardi, as well as two Hottentots. The party set out on 7 September with just one cart with three pairs of oxen, and saddle-horses. They travelled to Groene Kloof, which is present-day Mamre, where they remained a whole week, botanizing. 'The sandy and low plains, which we traversed, abounded at this time in bulbous plants, besides others which were now sprung up in consequence of the heavy rains that had fallen during the winter, and which with their infinitely varied flowers decorated these otherwise naked heaths.'

This was the start of a four-month expedition, which first took Thunberg north to the Winterhoek and Witsenberg Mountains, then southeastwards to Swellendam. There they could exchange the poor cart for a larger one with a sail-cloth cover and acquired ten fresh oxen and continued eastwards. Travelling was dangerous in many areas, roads and tracks were bad, and wildlife abounded, even lions, leopards, buffaloes, rhinos and elephants. In a forest near Knysna the party was attacked by a buffalo bull, killing two horses and chasing the men up the nearest trees. No one was hurt, but everybody was affected by the nasty experience. The sergeant was crying, and the gardener 'could scarcely speak for some days after', recorded Thunberg. His fellow travellers even wanted to interrupt the journey and return to the Cape, 'where they might get more wine to drink, and be less liable to be frightened by buffaloes.' But Thunberg persuaded them to go on, and after passing through Lange Kloof they eventually reached the eastern border of the Colony at Gamtoos River. Hippos were abundant in the river, Hottentots and Bantu people lived there together, and beyond the river lay the unexplored so-called Kaffir country.

In December they turned back, travelling partly along new tracks, and after New Year 1773 they were back in Cape Town. Thunberg remained there until the next spring. He was busy with his harvest of specimens and dispatched large parcels to his friends and benefactors in Holland and Sweden, including Linnaeus. He also practised medicine on a small scale, to improve his financial situation.

But there was also time for short excursions in the vicinity. For some weeks Thunberg joined forces with the French explorer Sonnerat. They collected plants and birds around Constantia, and one day they climbed Table Mountain together. They found 'the pride of Table Mountain', *Disa uniflora*, and also its relative, *Disa longicornu*. On that single day Sonnerat collected 300 species of plants and wore out three pairs of shoes, returning barefoot to the town.

In the middle of May, Thunberg went on a hike together with Captain Robert J. Gordon and the English gardener Francis Masson, who had recently arrived in the Cape. Gordon later became famous as commander of the Cape garrison and for his five expeditions into the interior. Masson became the faithful companion of Thunberg during the later two expeditions. They walked together via Chapman's Peak across the Peninsula to present-day Simonstown and back via Muizenberg.

In September a new expedition was prepared, with financial help from Thunberg's friend Mr Olof M. Berg. Thunberg acquired a good cart covered with sail-cloth, and his fellow traveller Masson already had a fine cart and a European coachman. They also took saddle-horses and four Hottentot servants with them.

They journeyed northwards, crossed the Berg River by ferry after a detour, and traversed the Olifants River Mountains with difficulty. Thunberg's cart needed repair, and in the meantime the two companions went on horseback through Elands Kloof to the Cold Bokkeveld. Passing through the Ceres area, they could join the rest of the expedition in Roodezand, which is close to present-day Tulbagh. These were areas already known to Thunberg from the first expedition, but he could make supplementary investigations of the surroundings, including the Winterhoek Mountains.

Following a similar route to the first journey, they arrived at Swellendam and proceeded eastwards, this time crossing the Gamtoos River and reaching as far as the Sundays River, north of present-day Port Elizabeth. Among the abundant wildlife there were quaggas, now extinct, and many carnivores. For safety reasons Thunberg reinforced his party with Hottentot troops, and at times there were more than 100 persons. European colonization was prohibited in this area, but Thunberg nevertheless came across a farmer, who had settled illegally with his family near Coega.

Thunberg had hoped to go to the Sneeuwbergen, but the horses became sick and the Hottentots abandoned the party, so the decision was taken to return. They went along a more northerly route than on the first journey, and from a peak in the Great Swartbergen range Thunberg could get a view of the wide and barren Great Karoo.

In the Little Karoo, Thunberg and Masson lost their way while on a horse-riding tour and had to spend one night in the open, and they were quite exhausted and starved when they rejoined the expedition. In the Riviersonderend region the rare *bloubok* (*Hippotragus leucophaeus*) still existed, although in scarce numbers. It became extinct about 25 years later (Rookmaaker 1989).

They returned to Cape Town at the end of January 1774, and Thunberg again became occupied with the collections. The next winter was very cold—Table Mountain and Devil's Peak were white with snow and hail some days, and vegetables and grapevines froze to death. Nevertheless, Thunberg kept his habit of making short excursions in the vicinity.

He also made the acquaintance of Lady Anne Monson, an eccentric British Lady, who accompanied her husband on his way to service in India. Her greatest passion besides moving in society was collecting natural history specimens. Linnaeus already in 1767 had named the Old World (but mainly South African) genus *Monsonia* after her. Before departing to Calcutta she gave a precious ring to Thunberg, which he valued highly.

At this time Thunberg also had an offer to go to Madagascar with one of the Company's slave ships. He declined, but instead recommended his compatriot Franz Pehr Oldenburg, who was a soldier at the garrison and who had accompanied Masson on his first expedition, and who had also been with Thunberg on shorter excursions. Oldenburg had a good knowledge of plants and around 1772 sent a fine collection to Sir Joseph Banks in London. He went to Madagascar, where he soon died of a tropical disease.

Thunberg preferred to prepare for a third expedition in the Cape Colony and persuaded Masson to make company once again. On 29 September they started, northwards as usual, passing Paarl and Piketberg. They visited the well-known cave Heerenlogement, where travellers have written their names since the 17th century.

They crossed the Olifants River, passed the conspicuous plateaus of Matsikamma and the Giftberg, and then climbed the Bokkeveld Mountains. They found the *kokerboom*, which was known ever since Van der Stel's expedition to Namaqualand in 1685, but had no scientific name. Thunberg and Masson decided to name it *Aloe dichotoma*, but Masson now stands as the sole author, since he described it (Masson 1776), obviously with Thunberg's consent.

Further up on the plateau still higher mountains towered, the Hantam Mountains and Roggeveld, where they could explore botanically unknown territory. The weather was rough, and they had frost and snow even in December. The few settlers of this inhospitable area were partly nomadic, in summer growing wheat in the mountains, but in winter grazing their cattle in the lower karoo areas. The travellers were back in Cape Town just before the New Year.

Thunberg's sojourn at the Cape drew to its end and in March 1775 it was time to continue towards the East and the final destination, Japan. On the way he stayed one month in Java, where he mixed with the European colonists, made excursions, and bought unicorn (i.e. narwhal) horns, which could be sold at a profit in Japan.

In August he arrived in the harbour of Nagasaki, where all foreign visitors were confined to the little islet called Deshima. His freedom of movement was very limited, and only after half a year did he manage to get a temporary permit to botanize in the surroundings of Nagasaki. Deshima is not visible today, but a memorial stone marks the site. The stone was erected by Siebold in 1826 and carries the names of Kaempfer and Thunberg, pioneers in the exploration of Japan.

In 1776 Thunberg was allowed to join the Dutch legation on its annual visit to the shogun's court in Edo, which is now Tokyo. They travelled mainly by palanquin along main roads, and the journey to Edo lasted four months. Along the road Thunberg could make a good number of collections and observations. In spite of the restrictions, he was delighted and impressed by the Japanese culture and way of life. He saw beautiful temples and gardens, for example in Miaco (present-day Kyoto), and everywhere a well ordered society, which seemed to work smoothly and to everyone's satisfaction. He could not discern the ongoing political and economic decline, which was skilfully concealed by the despotic government.

In Edo, Thunberg met with many learned Japanese scholars, with whom he had daily conversations. The medical doctors, especially, were interested to acquaint themselves with Western medicine and natural history. Thunberg held regular courses with some of these scholars and gave them diplomas before his departure. With some of them he kept a correspondence long after his return to Sweden.

In this way Thunberg may have exercised an influence on the Japanese society, more far-reaching than mere scientific knowledge. His Western ideas may have catalyzed the historical processes in Japan, which eventually led to the Meiji restoration and the end of the long isolation of the country.

The audience took place on 18 May 1776, but Thunberg was not allowed to be present. However, the shogun was apparently curious about the visitors and is said to have appeared incognito among them to watch them more closely.

The return journey to Nagasaki followed the same route, and after 16 months in Japan, Thunberg was ready to embark on his homeward voyage. He visited Java and Ceylon on his way, about half a year on each island. He also made a brief visit at the Cape. He found that Cape Town had changed so much in three years that he hardly recognized it. He met with William Paterson, gardener and plant collector, who made important travels in the Cape over three years (1777–1780), but Thunberg was not too impressed with Paterson's botanical knowledge.

Thunberg left South Africa in May 1778 and arrived in Holland after four and a half months. Having concluded his business with the Company, benefactors and friends, he went to London in December, where he was warmly received by Sir Joseph Banks and Daniel Solander. He also visited the British Museum, Kew Gardens where he met the botanist/gardener Aiton, as well as Chelsea and other

gardens. Via Holland, Germany and a visit to the University of Greifswald, Thunberg was back in Sweden in March 1779, after nine years' travelling.

Back in Sweden, Thunberg became remarkably sedentary. He had been appointed Demonstrator at the Botanical Garden in Uppsala under the younger Linnaeus, who held the chair after his father. When Linné fil. went to London in 1781, Thunberg was acting for him, and the same year he was appointed 'extra ordinarie', i.e. associate professor of botany with an increase in salary. After the death of the younger Linnaeus, Thunberg was appointed to the chair, which had been held by 'four most celebrated men, two Rudbecks and two Linnaeus', using Thunberg's own words, and he kept this position until his death.

Thunberg continued to work on his collections and publish during all his long life. His main interests were the floras of South Africa and Japan, but he also wrote of insects, birds, fishes, mammals, minerals, Japanese coins, Swedish husbandry and so forth (Rookmaaker & Svanberg 1994). He became popular with students and took part in academic life, as vice-chancellor of the University four times, and conferring doctors' degrees even at an advanced age.

Thunberg was a member of the Swedish Academy of Sciences for 56 years, but only reluctantly did he go to the meetings in Stockholm, and he was President of the Academy only once, in 1784.

The Swedish King, Gustav III, was benevolent to Thunberg and in 1784 set aside part of the royal garden in Uppsala for a new botanical garden and had a new museum erected on the site. This was inaugurated in 1807, and the museum still houses the Thunberg herbarium. In 1785 the King also made Thunberg a Knight of the Order of Vasa, and in 1815 he became a Commander of the same order, a very rare honour not previously bestowed on any academic teacher.

In 1785 Thunberg donated his natural history collections to the University of Uppsala, where they were especially welcome, since the invaluable Linnaean collections had recently been sold to England.

Beside all his scientific publications, Thunberg published a narrative of his journey in four volumes. The Swedish original (Thunberg 1788–1793) was soon translated into English, German and French (Forbes 1986). Sparrman also wrote a travelogue, the first part of which was published five years earlier than Thunberg's (Sparrman 1783; Forbes 1975–1977). The style is very different, and a modern reader may find Sparrman's book more entertaining. Thunberg had no literary ambitions; he merely wanted to report as many facts and observations as possible, avoiding fanciful stories and undue digressions. Nevertheless, there are some exaggerations and improbabilities in the text, for example an account regarding the habits of lions and ways of hunting them. Also, in his eagerness to record and observe, Thunberg let slip some naiveties, such as a remark on the importance of water for navigation in Holland (in the English translation this passage is modified and no longer naive), or his observation that in France even simple people speak French fluently.

On his way home from Japan, Thunberg declined an offer to marry a rich and beautiful girl in Java, and he remained a bachelor until 1784, when he married Brigitta Charlotta Ruda. She was nine years younger than Thunberg and the daughter of the university accountant Ruda, in whose house Thunberg had served as a private teacher during his university studies. The marriage was childless, but two young relatives were adopted, a daughter Birgitta Elisabeth, and a son Per, who became a farmer. A third relative, Carl Peter Forsberg lived as son with the Thunbergs, but kept his family name. He took a doctor's degree in medicine, was appointed 'botanices demonstrator' and promoted in many ways by Thunberg until the death of the latter. He served as a medical doctor and died from smallpox, only 39 years old.

Thunberg was a generous, good-hearted person who cared also for his servants, relatives and friends, especially when they were in economic trouble. His own financial circumstances were never bright, and at one stage he was compelled to sell his private library, and he also considered selling his insect collection to St Petersburg. He has been described as a happy, lively and friendly person with a genuinely honest character. In his older days he became stone-deaf and was sometimes smiled at, when he appeared in an old-fashioned outfit in his antiquated horse-cart nicknamed 'Skallerormen' (the rattle-snake). When he died in 1828 at the age of 85, he was sincerely mourned and solemnly honoured.

THUNBERG'S CONTRIBUTIONS TO THE SOUTH AFRICAN FLORA

Most of Thunberg's about 200 botanical publications are concerned with South African flora. Already after his first expedition in the Colony he started to work on his collections and described plants new to science. His first botanical publication (Thunberg 1775a) deals with a a new 'palm', in reality a cycad, which he named *Cycas caffra*. Later (Thunberg 1782) he renamed it *Zamia caffra*. As a matter of fact, he mixed up two species, which are now called *Encephalartos longifolius* and *E. caffer*, and which he first encountered in November 1772 near the Gamtoos River, west of the present-day Port Elizabeth. He commented on the Hottentots' way of making bread from the pith of the stems.

In the same year Thunberg described a very peculiar plant, which he regarded as the most singular organism he had found during his travels (Thunberg 1775b). He named it *Hydnora africana* and thought it was a mushroom, although it had stamens and pistils. But it seemed to propagate by spores, and he therefore placed it in the class *Cryptogamia*.

The peculiar 'mushroom' was first shown to him by his friend the political secretary O.M. Berg, who had received it from a farmer in the northern part of the Colony. Thunberg planned his second expedition with the purpose of finding the strange plant, and he eventually found it in the Hantam Mountains north of Calvinia. He noted that it was a parasite on *Euphorbia* roots, and that the fruit was eaten by the Hottentots as well as by animals.

At home in Sweden, Linnaeus quickly realized that *Hydnora* was not a mushroom but a flowering plant, although *'singularis inter omnia vegetabilia'*, that is, unique amongst all plants. In Linnaeus's last dissertation, defended by Erik Acharius (1776), the plant was renamed *Aphyteia*, but Thunberg's generic name has priority, of course.

Thunberg had a certain stubbornness, perhaps because he was a Smolander, like Linnaeus, and held to the mushroom theory although he had realized the true nature of the plant (Thunberg 1777, 1808). As late as in the Schultes edition of *Flora capensis* (Thunberg 1823), he wrote of *Hydnora* that it belonged in reality to the mushroom family (*'Planta revera pertinet ad familiam fungorum ....'*).

After these perhaps somewhat stumbling steps on the road of botanical science, an unending row of publications followed, dealing with new genera or species from the Cape, or from Japan or Ceylon. Thunberg was a true Linnaean and he followed the method of Linnaeus closely, even if he ventured to introduce a change in the sexual system. Instead of the 24 classes of Linnaeus, Thunberg recognized only 20. Thunberg's friend and benefactor Bergius praised his innovation, but it was adopted by very few botanists and soon forgotten.

Thunberg's scientific strength was his discerning eye and descriptive capacity—God created, Linnaeus ordered, Thunberg described. He contributed substantially to the younger Linnaeus's work *Supplementum plantarum*, which was based on his father's unfinished *Mantissa tertia*. During the summer of 1779 Thunberg worked intensely with the younger Linnaeus to complete the work, which was published in 1782 (Linné fil. 1782). Thunberg's contribution was almost 500 new species from the Cape as well as several from the East Indies and Japan. However, he never got the credit, since they are all cited with Linné filius as author. Under the genus *Thunbergia*, Linné acknowledged Thunberg's contribution in the following words: *'Quantum illi debeo plurimae paginae hujus Opusculi ostendunt ...'* or 'How much I owe to him is testified by most pages in this work.'

Thunberg then concentrated on the Japanese plants and in 1784 published his *Flora japonica*, a fundamental work which soon became an indispensable classic (Thunberg 1784; Kimura 1977). It was a critical and comprehensive flora, summarizing the knowledge of the vascular plants of Japan, and containing much new information. The work was preceded by a critical examination and analysis of Engelbert Kaempfer's Japanese plants, which Thunberg had studied in London on his way home from his long journey.

Flora japonica contained 39 copper engravings of plants. Some closely match his specimens, such as the plate of *Hypericum japonicum*, exactly matching the original specimen in the Swedish Museum of Natural History. He also published *Icones plantarum japonicarum* (Thunberg 1794–1805), which appeared in five fascicles containing 50 plates, mainly copper engravings, but some in the newer technique of aquatint. Thunberg had several hundreds of more drawings which remained unpublished, due to the difficult times. Europe was torn by wars and

Sweden was involved in some of them, besides suffering from political and economic crises.

More than 300 illustrations of Thunbergian Japanese plants are preserved in St Petersburg, and they will be published in 1994, in Japan (Kimura & Leonov 1994). Nearly all of them can be matched with herbarium specimens in the Thunberg herbarium in Uppsala.

Thunberg also aimed at publishing 1 000 plates of Cape plants. His friend and correspondent Acharius, known as the founder of lichenology, was an accomplished artist and he prepared some 500 beautifully coloured drawings of Cape plants for Thunberg. These were never published, unfortunately, and it is not known whether they still exist.

Only black-and-white plates were published in some of Thunberg's numerous publications on the Cape flora. The *Prodromus plantarum capensium* (in two parts, Thunberg 1794 and 1800) contained a few, among them a plate of *Acharia*, which was executed by Acharius himself. The *Flora capensis* in its various issues (Thunberg 1807–1820) remained unillustrated, in spite of Thunberg's intentions. Some dissertations contain a few plates, mainly the early ones. Usually they match Thunberg's herbarium specimens, such as the *Gladiolus equitans* plate (Thunberg 1810), and 'the blushing bride', *Serruria florida*, first published as *Protea florida* (Thunberg 1781).

Just like Thunberg had contributed substantially to the younger Linnaeus's work, so did Olof Swartz assist his mentor and friend Thunberg with various publications. The voluminous correspondence between these two leading botanists in Sweden at the time bears witness to this cooperation. Swartz wrote part of the dissertation on *Ricinus* (Thunberg 1815), and authored, together with the young respondent L.J. Prytz, a dissertation on *Styrax* (Thunberg 1813). A series of papers on plants from Brazil, *Plantarum brasiliensium* (Thunberg 1817, 1818, 1821) also had Swartz as main author, even if this is not acknowledged by Thunberg.

Thunberg also made small contributions to the flora of Ceylon and Java (Thunberg 1825a, 1825b), but they are insignificant compared to his life-time studies on Japanese and South African plants. Altogether Thunberg described 74 new genera, and about 40 of these are still valid. Several of these are South African genera with such an isolated taxonomic position to merit their treatment as separate families: Achariaceae, Hydnoraceae, Montiniaceae, Oliniaceae, Retziaceae and Vahliaceae.

New species described by Thunberg amount to about 1 880 (Juel 1918), plus about 500 which he contributed to the *Supplementum plantarum* (Linné fil. 1782). In his later years the quality of the dissertations dropped, and some are mere lists of species earlier published, or catalogues of the natural history collections in the Uppsala Museum. He also wrote on the animals and plants of the Bible in a number of dissertations, which belong to his last published works.

Thunberg was also an eminent zoologist, particularly entomologist, and his name as original author is attached to many South African animals, from mammals like the brown hyaena to insects like the 'opblaser' grasshoppers, *Pneumora*, described in his first zoological paper (Thunberg 1775c).

Thunberg became the internationally most well-known Swedish scientist of his time. He was a member of 65 academies and learned societies and kept an extensive correspondence with colleagues in many countries. His adherence to the Linnaean method and his descriptive approach to taxonomy rendered him some criticism. The Italian traveller Acerbi, who visited Scandinavia around the turn of the century, wrote of Thunberg: 'he is taken up with too many objects and branches of natural history to be great in any of them', but Acerbi was unduly negative about most institutions and scientists in Sweden.

Thunberg laid the solid foundation for taxonomic botany in South Africa, and he is rightly called the 'Father of South African botany' (MacOwan 1887; Winquist 1978). Today the importance of taxonomy is more widely understood than perhaps one or a few decades ago. The need for basic knowledge of the biodiversity and its components is emphasized in many disciplines of biological science, including ecology, and is a prerequisite in conservation. Especially in areas of megadiversity and extremely high endemism, such as South Africa, taxonomy is an indispensable basic science. The need for continued research is obvious—every year new taxa are found and described, even in comparatively well-known and much studied groups of organisms, such as the vascular plants.

We owe much to Thunberg, and we have to continue in his footsteps. Let me conclude with the often cited words of the South African botanist Peter MacOwan, formulated more than a century ago: 'Nevertheless, as long as in our paradise of flowers there wanders a single botanist, so long will the name of Thunberg be held in honoured remembrance' (MacOwan 1887).

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Patterns of plant diversity and endemism in southern Africa: an overview

R.M. COWLING* and C. HILTON-TAYLOR**

* Institute for Plant Conservation, Department of Botany, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

** Conservation Biology Research Unit, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

ABSTRACT

Southern Africa has an extremely diverse flora with very high levels of endemism. The density of vascular plant species is on a par with many of the rich floras of tropical countries. The level of endemism is also very high, being more akin to those of oceanic islands than a portion of a continent. This endemic flora comprises a distinct phylogenetic assemblage, with 13 families being endemic to the region. This diversity is not uniformly distributed over southern Africa, but is concentrated in eight localized hot-spots. The diversity and levels of endemism within two of these, the Cape and the Succulent Karoo, are notable in comparison with similar areas elsewhere. The Cape flora in particular, is the richest of the world's hot-spots of plant diversity. The flora endemic to the southern African hot-spots is also not a random assemblage with regard to taxonomic composition, growth forms and other biological attributes. Of all the southern African hot-spots, the Cape and Succulent Karoo are most in need of conservation attention. Although the protected area network needs to be re-evaluated, considerable attention will have to be given to the sustainable use of biodiversity outside conservation areas. This is of particular importance in the light of the changing sociopolitical situation within South Africa.

INTRODUCTION

Internationally, most biodiversity analyses have focused on the extremely rich tropical regions of the earth (e.g. McNeely *et al.* 1990; Mittermeier 1988; Mittermeier & Werner 1990; Myers 1988). This focus on tropical countries has led to the neglect of biodiversity in temperate regions (Given 1990; McNeely *et al.* 1990; Platnick 1991), particularly the five warm temperate Mediterranean-climate regions of the earth which contain about 20% of the world's plant species, many of which are endemic to those regions.

Myers (1988) coined the term 'hot-spot' to describe areas that are characterized by high species richness, high concentrations of endemic species and which are experiencing high rates of habitat modification or loss. (The term hot-spot as defined by Myers (1988, 1990) is used throughout this paper.) Initially,

Myers (1988) identified 10 hot-spots, all in the tropical rainforests. He then extended his hot-spot analysis (Myers 1990) to include additional tropical rainforest regions and four of the Mediterranean-climate regions, including the Cape Floristic Region of South Africa. The total endemic flora of the 18 hot-spots identified by Myers (1988, 1990) comprises about 50 000 species or 20% of the world's total flora on only 0.5% of the earth's surface. The Cape Floristic Region, with over 6 000 endemic species, emerged as the 'hottest' of the world's hot-spots (Myers 1990).

The *Flora of southern Africa* (FSA) region (the area south of the Kunene, Okavango and Limpopo Rivers, see Figure 1, but excluding Angola, Mozambique and Zimbabwe) has long been recognized as an area of remarkable plant diversity with high levels of endemism (Adamson 1938; Cowling *et al.* 1989; Gibbs Russell 1985; Goldblatt 1978; Good 1974; Levyns 1964). At the latest count, the region's flora comprised 21 137 species of vascular plants (Arnold & De Wet 1993) of which at least 80% are endemic (Gibbs Russell 1985; Goldblatt 1978). These high levels of plant diversity and endemism are, however, not evenly distributed across southern Africa (Cowling *et al.* 1989; Davis & Heywood 1994; Gibbs Russell 1987;

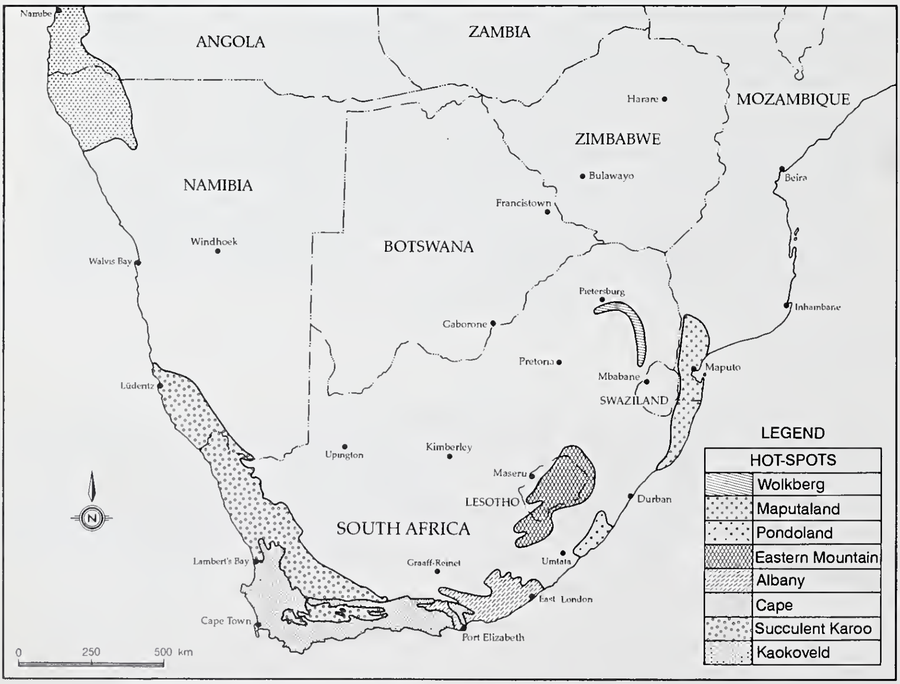

Figure 1.—Map of southern Africa (Botswana, Lesotho, Namibia, South Africa and Swaziland) with shaded areas indicating location of hot-spots mentioned in the text.

Weimarck 1941). Although patterns of plant species richness at the regional level have been analysed for southern Africa (Cowling *et al.* 1989; Gibbs Russell 1987) and Centres of Plant Diversity (Davis & Heywood 1994) have recently been described (Hilton-Taylor 1994a, 1994b; Killick 1994; Rebelo 1994a; Van Wyk 1994), there has been no subcontinental-level study of patterns of plant endemism. The aims of this paper are therefore (1) to compare the species richness (for the purposes of this paper we have referred to species richness as diversity) and levels of endemism of the southern African (the FSA region as defined above) flora with other areas of the world; (2) to identify the hot-spots of plant diversity and endemism within southern Africa; (3) to determine whether the hot-spot endemics have any special characteristics; (4) to describe the major threats to the flora, particularly in the hot-spots; and (5) to propose methods of ensuring the conservation of plant resources.

Our analysis includes data only for the vascular plants (gymnosperms and angiosperms) and the nomenclature used follows that in Arnold & De Wet (1993). We have also assumed that all species are of equal rank when used as measures of biotic diversity, despite the fact that it is unreasonable to give equal biotic or conservation value to each one of the 526 species of *Erica* endemic to the Cape Floristic Region, and to the phylogenetically and ecologically unique Namib Desert endemic, *Welwitschia mirabilis* (see Bond 1989). Although there are methods for ranking species on the basis of their genetic diversity (e.g. Crozier 1992; Vane-Wright *et al.* 1991; Williams *et al.* 1991), such an approach was deemed impractical for the purposes of this study. This type of approach is also premature if one considers the number of large and important families in the flora for which there is no recent and/or adequate taxonomic treatment.

THE SOUTHERN AFRICAN FLORA

Biodiversity

Southern Africa has a remarkably rich flora of vascular plants, with 23 404 taxa (species plus infraspecific taxa) being recorded from the region (Arnold & De Wet 1993), and it also has one of the highest species densities in the world (Table 1) (see also Cowling *et al.* 1989; Gibbs Russell 1985). Species richness for the subcontinent is higher than 8 of the 12 ‘megadiversity countries’ identified by McNeely *et al.* (1990), namely Australia, Ecuador, India, Indonesia, Madagascar, Malaysia, Peru and Zaïre (Figure 2). In contrast to the above countries, southern Africa is a predominantly warm-temperate, semi-arid region with an overall mean annual rainfall of less than 400 mm (Schulze & McGee 1978). The amount and seasonality of rainfall do, however, vary considerably from north to south and from west to east across southern Africa, e.g. in the northwest, mean annual rainfall is less than 100 mm and occurs predominantly in the summer months; in the southwest it is 600 mm and occurs predominantly in the winter months; and in the eastern parts it may exceed 1 400 mm and occurs mainly in summer (Schulze & McGee 1978). Rainforests cover less than 1% of southern Africa (Rutherford &

TABLE 1.—Vascular plant species density in southern Africa and similar-sized regions

Region	Area (10^6 km^2)	Species density ($\times 10^3/10^6$ km^2)
Southern Africa	2.57	8.22
Zaïre	2.35	4.68
Argentina	2.77	3.25
Algeria	2.38	1.30
Sudan	2.51	1.27

Sources: World Conservation Monitoring Centre (1992, except for southern Africa (Arnold & De Wet 1993).

Westfall 1986), whereas most other species-rich regions include large areas of tropical rainforest (McNeely *et al.* 1990; Myers 1988, 1990).

A detailed assessment to determine why the southern African flora is so rich is beyond the scope of this paper, but much of the region's biodiversity can be attributed largely to contemporary ecological conditions. The subcontinent's transitional location relative to the subtropical summer rainfall and temperate winter

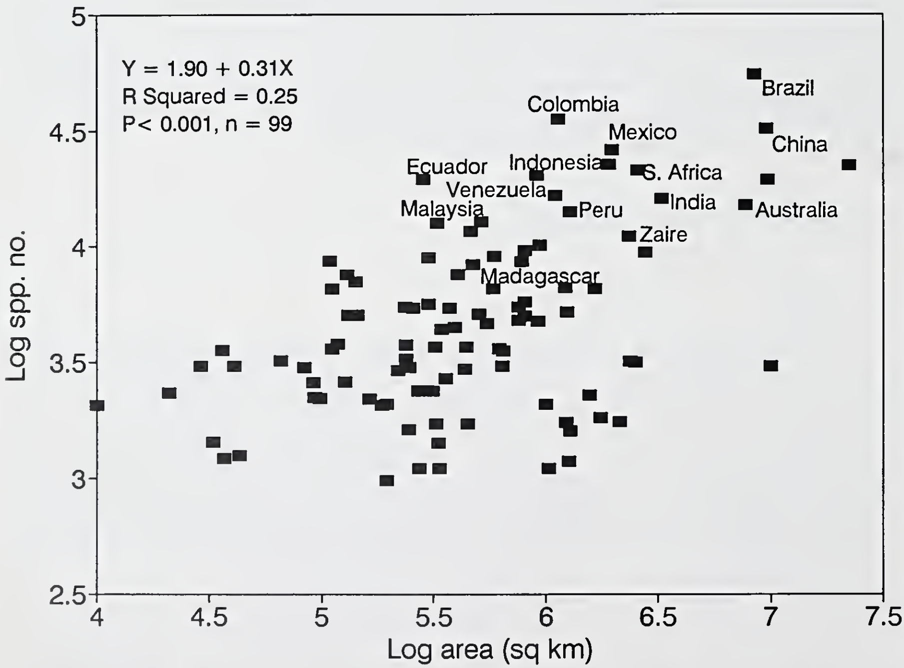

Figure 2.—Species-area relationships (vascular plants only) for 100 countries. Other than southern Africa and Venezuela, all the listed countries are the 'megadiversity countries' of McNeely *et al.* (1990). (Source: World Conservation Monitoring Centre 1992.)

rainfall climates, combined with a complex topography and heterogeneity of geology and soils (Rutherford & Westfall 1986; Werger 1978a), results in steep ecological gradients along which many species can occur (Cowling *et al.* 1989). The heterogeneity of the region is well illustrated by its classification into five phytochoria (Werger 1978b; White 1983), seven biomes (Rutherford & Westfall 1986) and, in South Africa alone, 70 major vegetation categories or Veld Types (Acocks 1953). Despite this heterogeneity, there are more species in southern Africa than in ecologically similar regions elsewhere in the world. This implies that unique historical processes have also contributed to the region's phenomenal biodiversity (Cowling *et al.* 1989, 1992).

Endemism

The number of vascular plant species endemic to southern Africa is exceptionally high, being more like what might be expected of an oceanic island than of a part of a continent (Goldblatt 1978; Table 2). This endemism is largely attributed to the diverse ecological conditions of southern Africa relative to the the rest of the continent. However, it is also the product of high speciation within some of the 560 genera endemic to the region, resulting in an island-like species : genus ratio of 9.6 (Gibbs Russell 1985; Goldblatt 1978). Most of these large genera are confined to the predominantly winter rainfall Fynbos and Succulent Karoo Biomes (Gibbs Russell 1987).

On a global scale, the flora endemic to southern Africa comprises a distinct phylogenetic assemblage. Examining the 26 largest families of flowering plants in the flora, which have levels of endemism significantly higher than or the same as the total flora, only eight rank among the 30 largest families in the world (Table 3). Southern Africa contains most of the world's species of Mesembryanthema [this is a monophyletic group within the family Aizoaceae without a taxonomic

TABLE 2.—Global patterns of vascular plant species endemism

Country	Endemism (%)	Country	Endemism (%)
New Zealand	82	Ecuador	21
Southern Africa	80	United States	21
Australia	80	Costa Rica	15
New Caledonia	80	Greece	15
Madagascar	68	Mexico	14
Indonesia	67	Panama	14
China	56	Algeria	8
Papua New Guinea	55	Mozambique	4
Chile	51	Nigeria	4
Zaïre	29	Zambia	4
Sri Lanka	28	Zimbabwe	2
Argentina	25	Germany	<1
Angola	24	Sweden	<1

Source: World Conservation Monitoring Centre (1992).

TABLE 3.—Species endemism in the 30 largest families of flowering plants in the flora of southern Africa

Family	Rank in sthn Afr.	Rank in world	Number of species (%) Endemic	Nonendemic	χ^2
Total flora	—	—	16 298 (80)	4 074 (20)	—
Endemism significantly higher than total flora					
Mesembryanthema†	1	—	2 360 (98)	48 (2)	552.0***
Asteraceae	2	1	1 820 (86)	296 (14)	52.9***
Liliaceae *s.l.*	4	11	943 (89)	123 (11)	49.8***
Iridaceae	5	—	828 (97)	30 (3)	151.4***
Ericaceae	6	21	802 (99)	2 (1)	202.8***
Asclepiadaceae	8	13	668 (87)	101 (13)	23.1***
Scrophulariaceae	9	8	471 (87)	72 (13)	16.5***
Proteaceae	13	—	355 (97)	11 (3)	66.2***
Rutaceae	15	—	274 (94)	17 (6)	36.1***
Restionaceae	16	—	265 (94)	17 (6)	34.0***
Geraniaceae	17	—	257 (96)	10 (4)	43.6***
Campanulaceae	18	—	236 (92)	20 (8)	23.3***
Crassulaceae	20	—	190 (89)	25 (11)	9.0**
Selaginaceae	21	—	208 (97)	10 (3)	31.7***
Polygalaceae	23	—	179 (88)	26 (12)	6.5*
Oxalidaceae	25	—	191 (98)	4 (2)	38.5***
Thymelaeaceae	26	—	180 (95)	9 (5)	26.7***
Aizoaceae *s.s.*	27	—	180 (98)	4 (2)	35.8***
Apiaceae	28	17	162 (90)	14 (10)	9.0**
Santalaceae	29	—	166 (94)	10 (6)	21.8***
Endemism same as total flora					
Euphorbiaceae	11	6	367 (80)	94 (20)	0.0NS
Orchidaceae	12	2	353 (81)	86 (19)	0.0NS
Amaryllidaceae	24	—	162 (82)	36 (18)	0.3NS
Sterculiaceae	30	—	148 (85)	27 (15)	2.0NS
Endemism significantly lower than total flora					
Fabaceae	3	3	1 147 (75)	393 (25)	31.4***
Poaceae	7	4	348 (44)	435 (56)	641.2***
Cyperaceae	10	9	240 (52)	224 (48)	235.5***
Acanthaceae	14	15	233 (66)	118 (34)	40.5***
Lamiaceae	19	7	142 (63)	83 (37)	39.5***
Rubiaceae	22	5	108 (52)	99 (48)	99.5***

World rank is among the 30 largest families.
*** = P<0.001; ** = P<0.01; * = P<0.05; NS = not significant.
Source: Gibbs Russell (1985).
† Mesembryanthemaceae sensu Dyer (1975).

rank, which comprises the two subfamilies Mesembryanthemoideae and Ruschioideae (Hartmann 1991)], Ericoideae (Ericaceae), Aizoaceae, Amaryllidaceae, Iridaceae and Restionaceae, as well as high proportions of Geraniaceae, Proteaceae and Rutaceae (Gibbs Russell 1985; Goldblatt 1978). In addition,

southern Africa has 13 endemic or near-endemic families, namely Achariaceae, Geissolomataceae, Bruniaceae, Grubbiaceae, Greyiaceae, Heteropyxidaceae, Penaeaceae, Rhynchocalycaceae, Aitoniaceae, Roridulaceae, Retziaceae, Stilbaceae and Lanariaceae (Dahlgren & Van Wyk 1988). Most of these familes are monogeneric with one, two or three species, the largest being the Bruniaceae with 76 species in 13 genera (Arnold & De Wet 1993; Goldblatt 1978). Nearly all of the above-mentioned families are concentrated in the winter rainfall region in the southwestern subcontinent. Families with levels of endemism significantly lower than the total flora (e.g. Fabaceae, Poaceae and Rutaceae) are widespread in other parts of the world.

SOUTHERN AFRICAN HOT-SPOTS

As mentioned previously, biodiversity is not uniformly distributed over southern Africa and some areas are clearly more species-rich than others. For example, Namibia which comprises 32% of the region's area has only 15% of southern African plant species, whereas the Cape Floristic Region, covering 3.5% of the region, has 41% of the species.

Under the auspices of the IUCN's Centres of Plant Diversity Project, seven centres of plant diversity have been identified in southern Africa (Davis & Heywood 1994). The criteria used for the inclusion of sites as Centres are that they must be both species-rich and have high levels of endemism. Most areas of southern Africa, but especially the region's centres of plant diversity (Davis & Heywood 1994), have been subject to, or are under threat from large-scale habitat modification and transformation (Macdonald 1989); hence we have used the term hot-spots (*sensu* Myers 1988) to describe these centres. We recognize eight hot-spots: seven Centres from Davis & Heywood (1994) and the Wolkberg Centre of Matthews *et al.* (1993). These hot-spots are distributed in an almost continuous arc below and including large portions of the Great Escarpment (Figure 1). They include the northeastern Transvaal Escarpment (Wolkberg), the Natal Drakensberg and associated uplands (Eastern Mountain), the coastal forelands of Maputaland, Pondoland and Albany, the entire Cape Floristic Region (Cape) and Succulent Karoo, and an outlier, the Kaokoveld, in northwestern Namibia and southwestern Angola. (It should be noted that although the study area for this paper is the FSA region, an area which is based on political boundaries, two of the hot-spots (Kaokoveld and Maputaland) extend northwards (Figure 1) outside the study area.) These hot-spots comprise diverse environments and vegetation types, ranging from humid summer rainfall areas with subtropical rainforests to arid winter rainfall climates with dwarf succulent shrublands (Table 4).

Biodiversity and endemism

When compared to other recognized hot-spots, southern African hot-spots are not particularly rich in plant species, with the exception of the Cape Floristic Region and Succulent Karoo (Figure 3). For its size, the Cape Floristic Region is

TABLE 4.—Characteristics of southern African hot-spots

Hot-spot	Area (km^2)	Number of species	Endemics (%)	Rainfall ($mm\ yr^{-1}$)	Rainfall (season)	Vegetation
Wolkberg	5 980	2 700	4	500–2 000	Summer	**Temperate and subtropical grassland** and rainforest, savanna
Maputaland	26 734	1 100	15	600–1 200	Summer	**Savanna**, subtropical rainforest and grassland, wetland
Eastem Mountain	40 000	1 750	30	1 500–2 000	Summer	**Temperate grassland** and rainforest, sclerophyll shrubland
Pondoland	1 880	1 500	8	1 000–2 000	Summer	**Subtropical grassland** and rainforest
Albany	22 500	2 000	10	350–750	All year	**Subtropical thicket**
Succulent Karoo	111 212	4 750	35	20–300	Winter to all year	**Succulent shrubland**
Cape	90 000	8 600	68	250–3 000	Winter to all year	**Sclerophyll shrubland**, temperate rainforest
Kaokoveld	70 000	952	12	10–300	Summer	**Deciduous shrubland**, ephemeral herbland, savanna

Species number includes vascular plants only.
Dominant vegetation is in boldface.
Sources: Davis & Heywood (1994); Matthews *et al.* (1993).

the richest of the Mediterranean-climate region hot-spots and has more species than many tropical rainforest areas of similar size (Cowling *et al.* 1992). The richness of the Succulent Karoo flora is exceptional for a semi-arid region, both in terms of established hot-spots, but especially in comparison with regions of similar semi-arid environments (Figure 4; Cowling *et al.* 1989; Hilton-Taylor 1994a).

Endemism in southern African hot-spots ranges from 4% (Wolkberg) to 68% (Cape), with an average of 23% (Table 4). This is half the average value of 44% recorded for tropical rainforest areas and about a third of the average value of 58% recorded for Mediterranean-climate regions. However, with 6 000 endemic species, the Cape is the world's 'hottest' hot-spot (Myers 1990). The Succulent Karoo, with approximately 1 660 endemic plant species, ranks as the only semi-arid region to qualify as a hot-spot of global significance.

There is a total of 8 830 endemic plant species in southern African hot-spots, comprising 52.2% of the region's endemic flora in 12.1% of its area (Table 5). These hot-spots include about 3.5% of the world's flora on 0.2% of the earth's surface, a ratio considerably higher than, for example, Mediterranean-climate and tropical rainforest regions (see Table 5). Therefore, although the levels of endemism and numbers of species are not always the highest, the exceptional species : area ratio shows that the hot-spots of southern Africa should be counted among the world's most important areas for conservation action.

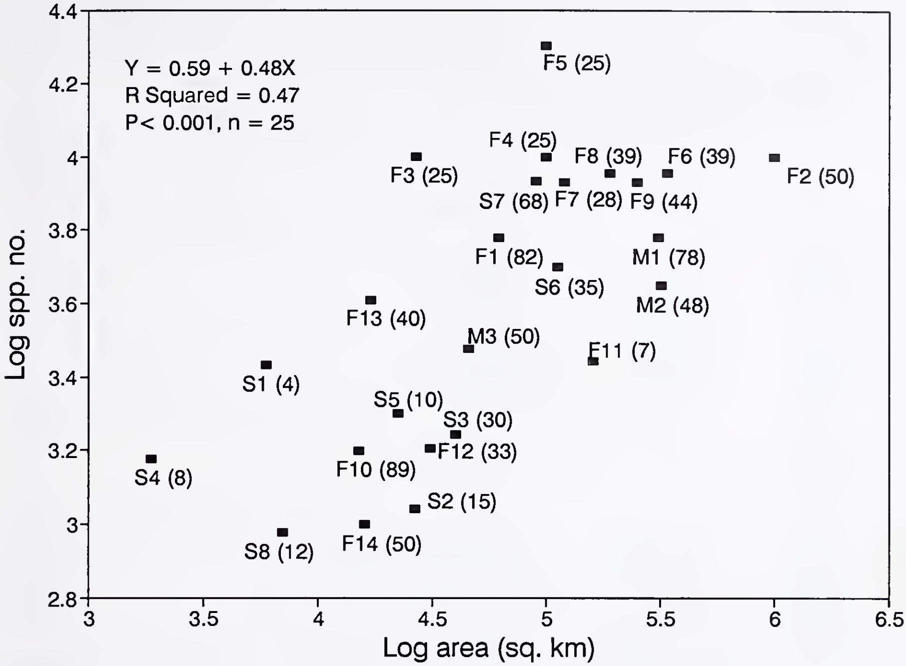

Figure 3.—Species-area relationships (vascular plants only) for southern African (S), Mediterranean-climate (M) and tropical rainforest (F) hot-spots. S1 = Wolkberg, S2 = Maputaland, S3 = Eastern Mountain, S4 = Pondoland, S5 = Albany, S6 = Succulent Karoo, S7 = Cape, S8 = Kaokoveld. M1 = South Western Australia, M2 = California Floristic Province, M3 = Central Chile. F1 = Madagascar, F2 = Atlantic coastal Brazil, F3 = Western Ecuador, F4 = Colombian Choco, F5 = Upland western Amazonia, F6 = Eastern Himalaya, F7 = Penisular Malaysia, F8 = Borneo (north), F9 = Philippines, F10 = New Caledonia, F11 = SW Ivory Coast, F12 = Eastern Arc Mts (Tanzania), F13 = Western Ghats (Tanzania), F14 = SW Sri Lanka. Figures in parentheses indicate the percentage of species endemic to the area. (Sources: Davis & Heywood 1994; Hopper 1992; Matthews *et al.* 1993; Myers 1988, 1990.)

TABLE 5.—Numbers of endemic species in southern African and other hot-spots

Hot-spot area	Area (km^2)	% earth's area	Number of endemic species	Endemics as % of total plant species
Tropical rainforests	2 428 000	1.6	37 235	14.9
Mediterranean-climate	765 400	0.5	14 165	5.6
Southern Africa	305 306	0.2	8 830	3.5
Total	3 408 706	2.2	54 382	21.8

Area of hot-spots includes transformed land (cf. Myers 1988, 1990).
Cape is included in both Mediterranean-climate and southern African hot-spots but duplication has been avoided in the totals. Sources: Myers (1988, 1990); Table 4.

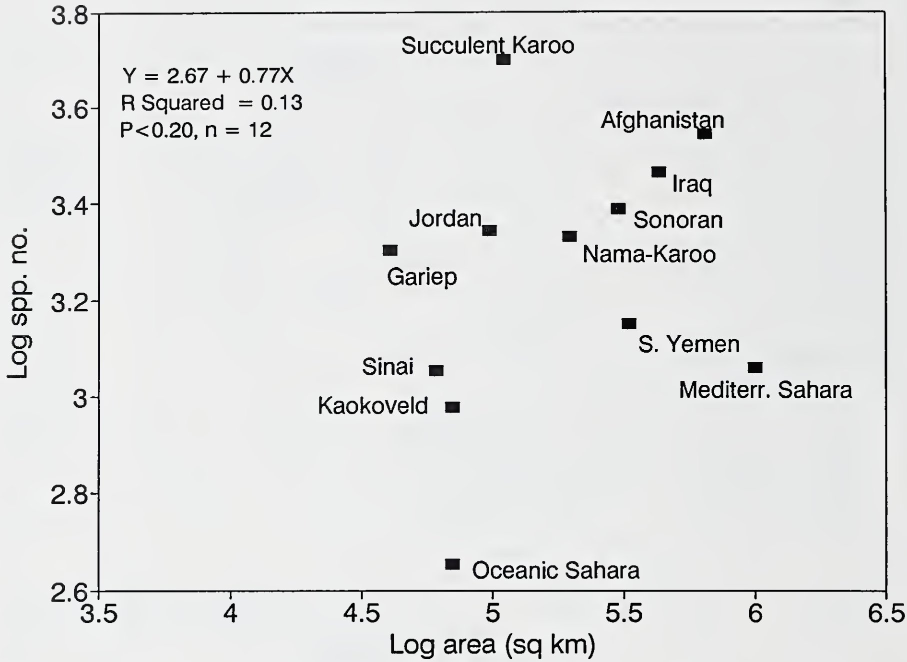

Figure 4.—Species-area relationships (vascular plants only) for arid and semi-arid regions of the world. (Sources: Cowling *et al.* 1989; Goldblatt 1978; Hilton-Taylor 1994b; Le Houérou 1992; World Conservation Monitoring Centre 1992; Hilton-Taylor unpublished data.)

Characterization of the endemic flora

In this section we investigate whether the endemic floras of the hot-spots are random assemblages with regard to their taxonomic affinities and biological traits.

Taxonomic aspects

An analysis of the floras from distinct portions of three hot-spots shows that taxonomically the endemics in southern African hot-spots are not a random assemblage (Table 6). The floras investigated were from the Agulhas Plain (Cape), southern Natal Drakensberg (Eastern Mountain) and the Gariep (mountainous area along the lower Orange River in the Succulent Karoo) (Figure 1).

In the southern Natal Drakensberg, families with higher than average levels of endemism include Asteraceae, Scrophulariaceae and Ericaceae. Most of the larger families have similar proportions of endemics as the total flora and endemics are significantly underrepresented in Poaceae and Orchidaceae.

TABLE 6.—Species endemism in largest families of flowering plants for selected areas within three southern African hot-spots

Family	Number of species (%) Endemic	Nonendemic	χ^2
EASTERN MOUNTAIN: SOUTHERN NATAL DRAKENSBERG (1 115 km²)			
Total flora	373 (29.3)	898 (70.7)	—
Endemism significantly higher than total flora			
Asteraceae	118 (41.5)	167 (58.5)	35.7***
Scrophulariaceae	36 (45.6)	43 (54.4)	9.9**
Ericaceae	15 (57.6)	11 (42.3)	8.9*
Endemism same as total flora			
Liliaceae *s.l.*	20 (23.8)	64 (76.2)	1.1NS
Fabaceae	14 (21.5)	51 (78.5)	1.6NS
Iridaceae	20 (30.8)	45 (69.2)	0.0NS
Cyperaceae	14 (23.7)	45 (76.3)	0.7NS
Asclepiadaceae	13 (29.5)	31 (70.5)	0.0NS
Campanulaceae	9 (36.0)	16 (64.0)	0.3NS
Apiaceae	7 (33.3)	14 (66.6)	0.0NS
Gentianaceae	6 (28.6)	15 (71.4)	0.0NS
Crassulaceae	6 (30.0)	14 (70.0)	0.0NS
Geraniaceae	5 (25.0)	15 (75.0)	0.0NS
Endemism significantly lower than total flora			
Poaceae	19 (17.6)	89 (82.4)	7.3**
Orchidaceae	15 (18.1)	68 (81.9)	4.9*
CAPE: AGULHAS PLAIN (1 609 km²)			
Total flora	513 (29.3)	1 238 (70.7)	—
Endemism significantly higher than total flora			
Ericaceae	80 (64.5)	44 (35.5)	78.1***
Restionaceae	35 (39.8)	53 (60.2)	4.4*
Mesembryanthema	26 (44.8)	32 (55.2)	6.2*
Proteaceae	39 (67.2)	19 (32.8)	39.8***
Rutaceae	34 (72.3)	13 (27.7)	41.1***
Polygalaceae	19 (54.3)	16 (45.7)	9.6**
Endemism same as total flora			
Asteraceae	52 (25.6)	151 (74.4)	1.3NS
Iridaceae	38 (25.5)	111 (74.5)	0.9NS
Fabaceae	49 (35.5)	89 (64.5)	2.5NS
Campanulaceae	14 (26.9)	38 (73.1)	0.1NS
Thymelaeaceae	15 (41.7)	21 (58.3)	2.1NS
Endemism significantly lower than total flora			
Poaceae	3 (4.6)	62 (95.4)	19.0***
Liliaceae *s.l.*	12 (16.0)	63 (84.0)	6.0*
Cyperaceae	7 (11.1)	56 (88.9)	9.5**
Scrophulariaceae	8 (14.3)	48 (85.7)	5.6*
Orchidaceae	2 (5.3)	36 (94.7)	9.7**
SUCCULENT KAROO: GARIEP (40 931 km²)			
Total flora	397 (19.8)	1 613 (81.2)	—
Endemism significantly higher than total flora			
Mesembryanthema	140 (54.7)	116 (45.3)	229.6***
Crassulaceae	40 (40.8)	58 (59.2)	27.5***
Asclepiadaceae	23 (42.6)	31 (57.4)	16.8***
Endemism same as total flora			
Liliaceae *s.l.*	37 (21.6)	134 (78.4)	2.6NS
Fabaceae	17 (18.3)	76 (81.7)	0.1NS
Iridaceae	18 (30.0)	42 (70.0)	3.5NS
Geraniaceae	15 (26.8)	41 (73.2)	1.4NS
Euphorbiaceae	11 (20.0)	44 (80.0)	0.0NS
Chenopodiaceae	6 (14.3)	36 (85.7)	0.5NS
Acanthaceae	3 (7.9)	35 (92.1)	2.7NS
Amaryllidaceae	11 (33.3)	22 (66.6)	3.1NS
Zygophyllaceae	2 (6.1)	31 (93.9)	3.1NS
Brassicaceae	5 (17.2)	24 (82.8)	0.0NS
Endemism significantly lower than total flora			
Asteraceae	29 (9.8)	266 (90.2)	20.7***
Poaceae	9 (7.4)	112 (92.6)	11.5***
Scrophulariaceae	3 (3.4)	86 (96.6)	14.7***
Aizoaceae *s.s.*	1 (1.2)	79 (98.8)	16.8***
Sterculiaceae	1 (3.5)	28 (96.5)	3.9*

Species numbers include vascular plants only. *** = $P<0.001$; ** = $P<0.01$; * = $P<0.05$; NS = not significant.
Sources: Southern Natal Drakensberg (Hilliard & Burtt 1987); Agulhas Plain (Cowling & Holmes 1992); Gariep (C. Hilton-Taylor unpublished data).

In the lowland Agulhas Plain flora, endemics were significantly overrepresented in six families including typical Cape families such as the Ericaceae, Restionaceae and Proteaceae, but also the largely Karoo group, the Mesembryanthema (Table 6). In contrast to the Eastern Mountain flora, Asteraceae and Scrophulariaceae did not have proportionally high levels of endemism but in common with that flora, Poaceae and Orchidaceae were underrepresented in terms of endemics.

Like the Eastern Mountain flora, a higher than average endemism in the Gariep portion of the Succulent Karoo flora was associated with only three families (Table 6). These are all succulent families with large concentrations of species in the winter rainfall arid and semi-arid areas of southern Africa (Gibbs-Russell 1985; Hilton-Taylor 1987, 1994a; Van Jaarsveld 1987). Interestingly, the Mesembryanthema have produced numerous endemics in both dry karroid and wetter, fireprone fynbos habitats (Hartmann 1991). In common with the Cape Floristic Region flora, Poaceae and Scrophulariaceae in this Succulent Karoo flora are underrepresented in terms of endemics.

We conclude from these results that the taxonomic apects of endemism show greater differences than similarities across these three hot-spots. The same families have different proportions of endemics in each region. This is to be expected, given the very different ecological conditions in each of the hot-spots (Table 4). Nonetheless, families such as Poaceae and Orchidaceae have consistently low proportions of endemic species.

Biological aspects

The endemics from southern African hot-spots are not a random assemblage with regard to growth form and other biological attributes. In the southern Natal Drakensberg, endemic forbs and shrubs are more frequent, and other growth forms less frequent, than nonendemics (Figure 5A). Despite relatively large areas of forest in the Eastern Mountain and Wolkberg hot-spots, there are no endemic trees in either region; most endemics are forbs and low shrubs associated with grasslands (Hilliard & Burtt 1987; Killick 1994; Matthews *et al.* 1993). This is not the case for the Maputaland and Pondoland hot-spots which harbour a number of endemic tree species, although most of the endemics are either forbs or low shrubs of grassland habitats (Van Wyk 1990, 1994).

The biological aspects of endemism in the Cape Floristic Region have been well studied (Cowling *et al.* 1992; Cowling & Holmes 1992; McDonald & Cowling in press). From these studies it can generally be said that both the lowland and mountain floras exhibit a greater than average chance that an endemic will be a nonsprouting, low to dwarf shrub (Figure 5B) with soil-stored seed banks and short dispersal distances. In the Agulhas Plain flora both forbs and geophytes are underrepresented as endemics and tree endemics are absent (there are a few endemic trees elsewhere in the Cape Floristic Region). Levels of endemism among graminoids in the Cape hot-spot are the highest in comparison to those in

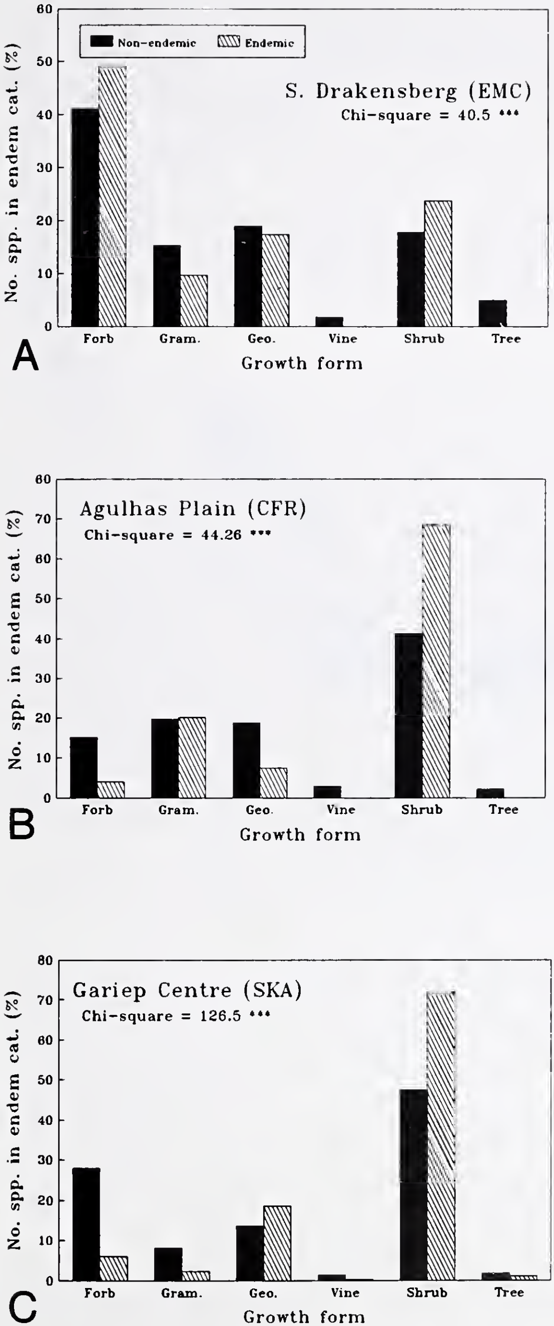

Figure 5.—Association between endemism and growth form in regional floras (vascular plants only) from portions of three southern African hot-spots. S. Drakensberg flora is from the Eastern Mountain hot-spot; Agulhas Plain from the Cape hot-spot; Gariep from the Succulent Karoo hot-spot. Gram. = graminoids; Geo. = geophytes. (Sources: Cowling *et al.* 1992; Hilliard & Burtt 1987; Hilton-Taylor unpublished data.)

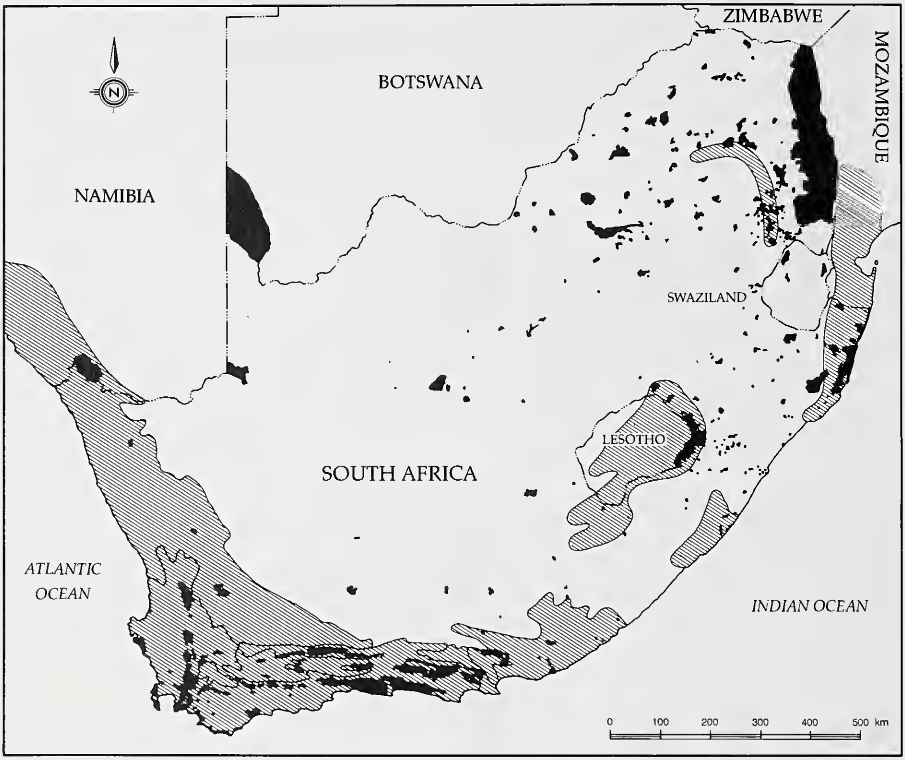

Figure 6.—Distribution of protected areas in South Africa (solid and dots) in relation to the hot-spots (hatched). (Source: adapted from an unpublished preliminary map of conservation areas produced by the Department of Environment Affairs in 1994.)

the other southern African hot-spots; this is due to the high number of endemics in the family Restionaceae.

The growth form profile of endemics in the Gariep flora (Succulent Karoo) is identical to an Albany flora profile (Cowling & Holmes 1991) and similar to that from the Cape except that the pattern for graminoids and geophytes is reversed (Figure 5C). An interesting pattern to emerge is that despite southern Africa having the richest petaloid geophyte flora in the world (Goldblatt 1978), endemic geophytes are more frequent than widespread species only in semi-arid winter rainfall areas. Succulents are enormously overrepresented as endemics in both the Succulent Karoo and Albany floras (Cowling & Holmes 1991; Hilton-Taylor unpublished). For example, in the Gariep flora 60% of endemics are succulents. Tree endemics in southern African arid areas are generally rare.

In conclusion, the biological aspects of endemism do show important differences across southern African hot-spots. Endemic forbs are common in moist,

summer rainfall eastern hot-spots; endemic shrubs are common in all hot-spots; endemic geophytes and succulents are common in the semi-arid southwest; and endemic trees are rare everywhere except for a relatively low occurrence in Maputaland and Pondoland.

Conservation

In this section we examine the conservation status of the hot-spots and the threats to the preservation of plant diversity in these regions. Wherever possible we draw on our analysis to make comments on conservation planning and management.

Conservation status

The protected area network in South Africa (we do not have information for the other countries in southern Africa) is not optimally located with regard to the region's hot-spots of plant diversity and endemism (Figure 6; Rebelo 1994b). Only in the case of the mountains of the Cape Floristic Region, and to a lesser extent the Wolkberg and Maputaland hot-spots, are reasonably large areas conserved (Table 7). Given the international significance of the Succulent Karoo as a semidesert hot-spot, the conservation status of the region is desperately poor (Hilton-Taylor & Le Roux 1989). The most alarming situation, however, is the highly inadequate conservation status of the lowlands of the Cape Floristic Region which harbour numerous endemic and threatened plant species (Rebelo 1992).

Both for its area and in an absolute sense, southern Africa has the highest concentration of *Red data book* plant taxa in the world (Figure 7). However, the

TABLE 7.—Conserved area and number of *Red data book* taxa in southern African hot-spots

Hot-spot	Area conserved (%)	*Red data book* taxa	
		Extinct	Other
Wolkberg	13.3	0	32
Maputaland	10.0	?	?
Eastern Mountain	5.5	0	27
Pondoland	7.0	0	33
Albany	6.5	1	51
Succulent Karoo	2.0	18	978
Cape: lowlands	3.0	29	1 406
mountains	50.0		
Kaokoveld	7.0	?	?

Conserved areas in Mozambique (Maputaland) and Angola (Kaokoveld) have been excluded. For the Cape hot-spot, the numbers of *Red data book* taxa given are for the whole region; separate figures for the lowlands and for the mountains are not available.
Sources: Davis & Heywood (1994); Everard (1988); Matthews *et al.* (1993); C. Hilton-Taylor (unpublished data).

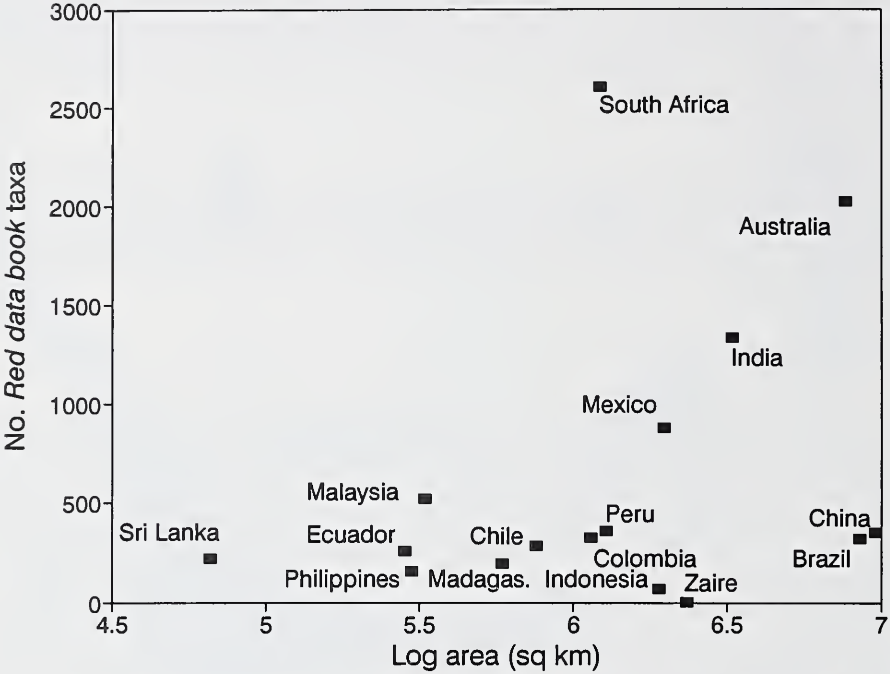

Figure 7.—Relationship between area and number of *Red data book* taxa in South Africa, the 'megadiversity countries' (McNeely *et al.* 1990) and other hot-spots (Myers 1988, 1990). All *Red data book* taxa are defined according to IUCN Red Data categories. Numbers include many taxa below species level. (Source: World Conservation Monitoring Centre 1992, except for South Africa: Hilton-Taylor unpublished data.)

TABLE 8.—Major threats to southern African hot-spots

Hot-spot	Threats
Wolkberg	Afforestation, invasive plants, overgrazing
Maputaland	Agriculture, afforestation, urbanization, overgrazing, plant harvesting, invasive plants, mining, tourism
Eastern Mountain	Overgrazing, agriculture, afforestation, plant harvesting, invasive plants
Pondoland	Overgrazing, veld burning, plant harvesting, agriculture, population growth
Albany	Overgrazing, agriculture, invasive plants, urbanization
Succulent Karoo	Overgrazing, mining, agriculture, plant harvesting
Cape	Invasive plants, agriculture (lowlands), urbanization, plant harvesting
Kaokoveld	Overgrazing, plant harvesting, tourism

Plant harvesting includes fuel wood, building materials, wild food and beverage crops, medicinal plants, wild flowers and succulents.
Source: Davis & Heywood (1994).

extent to which this is an artefact of inadequate data for other species- and endemic-rich areas is not known. There are at least 2 575 *Red data book* taxa (including both species and infraspecific taxa) recorded from southern African hot-spots (Table 7), representing about 98% of the total number recorded from the region (Hilton-Taylor unpublished data). Fifty-six per cent of these taxa occur in the Cape Floristic Region, where *Red data book* taxa show a very strong concentration in the lowland fynbos of the southwest, especially in the rapidly urbanizing areas of greater Cape Town (Rebelo 1992; Wood *et al.* 1994). Thirty-nine per cent of the *Red data book* taxa occur in the Succulent Karoo. The southwestern winter rainfall area is therefore extremely important as a repository of threatened and endemic plants.

Unfortunately the present IUCN threatened status categories used in classifying *Red data book* taxa do not provide an actual ranking of species from the most threatened to least threatened, and especially when dealing with large numbers of species as in the southern African case, are often too coarse to assist managers and conservationists in decision-making. However, the recent use of multivariate techniques by Given & Norton (1993) and Hall (1993) for assessing the threats faced by species and for determining priority groupings and rankings of threatened species, may provide a valuable tool for determining management and conservation priorities in southern Africa.

Threats

The major threats to the conservation of plant biodiversity in the southern African hot-spots are listed in Table 8. Specific details are given in the appropriate chapters in Davis & Heywood (1994), while Macdonald (1989) provides a general account of the impacts of land transformations and modifications on southern African biodiversity. The following major threats are briefly discussed here: (1) alien invasive plants; (2) afforestation; (3) land transformation for agriculture; (4) overgrazing; and (5) subsistence and commercial harvesting of indigenous plant products.

Invasive plants and afforestation are major threats to plant biodiversity in all hot-spots, with the exception of the Succulent Karoo and Kaokoveld (Table 8). In the Cape Floristic Region alien invasive plants have had an enormous impact on indigenous plant species and ecosystems (Richardson *et al.* 1992). The entire lowlands and most of the wetter mountain slopes have areas with moderate to dense infestations of alien species of *Acacia*, *Hakea* and *Pinus* (Richardson *et al.* 1992); these habitats also harbour a disproportionate number of endemic and threatened taxa (Cowling *et al.* 1992; McDonald & Cowling in press; Rebelo 1992). Even though alien thickets have negative economic costs due to their deleterious impact on water yields from mountain catchments, increased fire hazard and destruction of wildflower and ecotourism resources (Van Wilgen *et al.* 1992), it is unlikely that sufficient resources will be made available for the manual control of alien invasions in the future. The introduction of biological controls, some of which have been extremely successful (Dennill 1985; Hoffmann 1991; Hoffmann &

Moran 1988; Neser & Kluge 1986), is the only effective, long-term approach to this problem.

While alien invasions are also a problem in the wet, summer rainfall hot-spots, afforestation is a far greater threat to species conservation and ecosystem processes (Macdonald 1989). Of particular concern is afforestation of grassland habitats, areas which harbour a large proportion of the endemic and threatened species (Macdonald 1989; Matthews *et al.* 1993; Van Wyk 1994). For example, 30% of the *Red data book* plant taxa in the Transvaal occur in grassland habitats subject to afforestation, even though plantations presently cover only 2% of the province (Raal 1986).

Land transformation for agriculture is a major threat in the Cape Floristic Region, the wetter parts of the Succulent Karoo, and parts of Pondoland and Maputaland (Table 8). On the Cape lowlands, 79% of renoster shrubland and 49% of fynbos have been replaced by cereals, pastures and horticultural crops (Rebelo 1992, 1994a). The building of dams on mountain-fed perennial rivers in the southern Succulent Karoo has resulted in the transformation to irrigated lands of large areas of natural vegetation (Hilton-Taylor 1994a). More alarming is the extensive dry-land agriculture (2 269 km^2 in 1983) of southern Namaqualand (Macdonald 1989), an area too marginal for economically and ecologically sustainable agriculture (Hilton-Taylor 1994a).

With the exception of the Cape Floristic Region, overgrazing is a threat to biodiversity maintenance in all southern African hot-spots (Table 8). This threat is most severe in the communally owned land of Maputaland, Pondoland and the Succulent Karoo. However, extensive grazing-induced degradation, which reduces biodiversity and eliminates the endemic succulent and geophyte components, has also been recorded on privately owned farmlands in the Albany hot-spot (Hoffman 1989; Hoffman & Cowling 1990).

Subsistence and commercial harvesting of indigenous plant products is widespread in southern Africa (Cunningham 1989; Van Wilgen *et al.* 1992). In Maputaland, several rare and slow-growing species with medicinal value have been harvested almost to extinction (Cunningham 1989). Nonsustainable harvesting of fynbos for wild flowers (Van Wilgen *et al.* 1992) and the pillaging of succulents (Hilton-Taylor & Le Roux 1989) target precisely those taxa with high numbers of endemic species (Hilton-Taylor & Smith 1994).

CHALLENGES FOR THE FUTURE

Southern Africa is currently faced with uncertainty associated with the sociopolitical transformations occurring in South Africa. Although these changes may pose threats to plant conservation (Huntley *et al.* 1989), they also provide opportunities for new and appropriate interventions to prevent large-scale plant extinctions (Myers 1993) in southern African hot-spots.

Every effort must be made to establish southern Africa as a biodiversity hot-spot of international significance. Without this recognition, the subcontinent will continue to be overlooked by the international community when establishing priorities for funding and interventions. The appreciation by Myers (1990) of the status of the Cape Floristic Region as the world's 'hottest' hot-spot has contributed enormously to this end. Similarly, it is hoped that work on the Centres of Plant Diversity (Davis & Heywood 1994) will highlight the importance of the Succulent Karoo and other hot-spots in the region. The emergence of South Africa from a long period of political isolation may also result in an increasing awareness of the diversity of and threats to the region's biological resources.

The protected area network in the region must be re-evaluated in the light of the mismatch between reserve and hot-spot location (Figure 6; Rebelo 1994b). Priority areas for immediate action include the lowlands of the Cape Floristic Region (Rebelo 1992) and the Succulent Karoo (Hilton-Taylor 1994a; Hilton-Taylor & Le Roux 1989) (Table 7). However, despite the fact that a large percentage of the organisms making up our biodiversity is already preserved in the existing reserve network (Siegfried 1989), it is unlikely that extensions to the network will provide protection to representative examples of all ecosystems and sufficient numbers of populations of all species. Attention will rather have to be given to the sustainable use of biodiversity outside reserves.

With the current sociopolitical changes occurring in South Africa we also cannot afford to be complacent about the security of the existing protected areas. As pointed out by Grossman *et al.* (1992), all the protected areas are government subsidized and their persistence is subject to the taxpayers' goodwill and the health of the economy. With the increasing demands of other social priorities such as health, education and housing, why should state-financed, nonpaying ventures such as nature reserves be maintained?

A fast-growing literature in applied economics is showing that it is possible to estimate directly the value of environmental resources, including biodiversity (e.g. Tobias & Mendelsohn 1991; Western & Henry 1979). Southern Africa lags behind other developing regions in assessing the economic value of its natural ecosystems and indigenous biodiversity. The generation of income from the sustainable and imaginative use of the region's exceptional biodiversity will have to become the major economic engine for supporting conservation action, especially in the light of decreasing governmental funds for such purposes (Cowling 1993). Perhaps most importantly, in a subcontinent with a long history of dispossession, poverty and alienation from the natural environment (Ramphele & McDowell 1991), it is essential that the revenues generated from the utilization of our natural resources are used to provide tangible benefits to all those in the region who have been socially and politically marginalized.

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Botanical diversity and its conservation in Angola

B.J. HUNTLEY* and E.M. MATOS**

* National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.
** Departamento de Biologia, Universidade Agostinho Neto, C.P. 815, Luanda, Angola.

ABSTRACT

Angola is a large country (1.24 million km^2) with a rich but poorly documented botanical diversity. A wide range of ecosystems, from desert to rainforest, are represented in the six phytochoria (White 1983) found in the country. The Zambezian regional centre of endemism occupies over 80% of Angola, with the Karoo-Namib, Guineo-Congolian and Guinea-Congolia/Zambezia centres and transition zones making up most of the remaining area. Very small relic patches of Afromontane forest are found in the central western mountain zone, while a narrow tongue of the Kalahari-Highveld transition zone penetrates the southwestern escarpment foothills.

The present protected area network includes representative examples of 11 of the 32 major vegetation types recognized by Barbosa (1970). The expansion of this network to include examples of the Guineo-Congolian and Afromontane phytochoria and a better representation of vegetation types is proposed.

The impact of over 20 years of civil war on the conservation of botanical diversity is described and priorities for action are discussed.

INTRODUCTION

Angola is the second largest country in sub-Saharan Africa and includes an unusually wide diversity of habitats, from the vegetationless dunes of the Namib Desert to the tropical rainforests of Cabinda. Ironically, the rich biodiversity of Angola is poorly known. Before Independence was achieved in 1975, only two comprehensive studies of the country's vegetation had been published (Gossweiler & Mendonça 1939; Barbosa 1970), with a few further studies providing a little more detail of local areas (Teixeira *et al.* 1967; Teixeira 1968a; Matos & De Sousa 1970; Monteiro 1970; Menezes 1971). In contrast with the situation in most other African countries, an upswing in scientific and conservation action has not been witnessed in post-Independence Angola. The tragic consequences of the Angolan civil war which has continued unabated for 20 years have prevented any serious biological research and severely compromised the country's excellent network of national parks and reserves.

This paper will describe the major phytogeographic and vegetation characteristics of the country, and comment on the present situation and future prospects regarding biodiversity conservation.

PHYTOGEOGRAPHIC OUTLINE

A primary determinant of Angola's rich diversity of ecosystems is its great range of physical environments, particularly its physiographic and climatic features.

The country comprises four main physiographic components—a coastal plain from the Atlantic seaboard to approximately 200 m above sea level, and from 12 to 200 km wide; a narrow, steep escarpment, from 200 to 1 000 m altitude; an interior plateau, occupying nearly 80% of the country and lying between 1 000 and 1 600 m; and a mountain belt rising above the escarpment and plateau to 2 620 m in central western Angola.

The dominant geological feature of Angola is the division of the country, along a central, longitudinal axis, between Kalahari sands to the east and crystalline rocks to the west. Marine sediments (marls and limestones) and recent sands cover the coastal plain.

The predominant climatic influence is that of rainfall. The southwestern and coastal areas are strongly influenced by the cold Benguela Current. Relatively cool, desertic conditions prevail in the extreme southwest, while the entire coastal belt, even as far as the Zaïre River, is arid to semi-arid. The escarpment, mountains and interior plateau are much more humid, rainfall here ranging from 900 to 1 700 mm per annum.

The absence of a recent checklist of the flora of Angola is a serious impediment to any study of the patterns of diversity in the country. Furthermore, little is known or has been published on the evolutionary history of Angola's flora. The country's geographic position, with Zaïre to the north and northeast, Zambia to the east and Namibia to the south, accounts for the strong links with the floras centred in these regions. This is reflected in the presence in Angola of six of White's (1983) phytochoria (Figure 1):

- Guineo-Congolian regional centre of endemism
- Zambezian regional centre of endemism
- Karoo-Namib regional centre of endemism
- Afromontane archipelago-like regional centre of endemism
- Guinea-Congolia/Zambezia regional transition zone
- Kalahari-Highveld regional transition zone.

With the exception of South Africa, no other African country has as many phytochoria. It is therefore evident that the published estimate of 5 000 species of vascular plants in Angola (Stuart & Adams 1990) is a substantial underestimate.

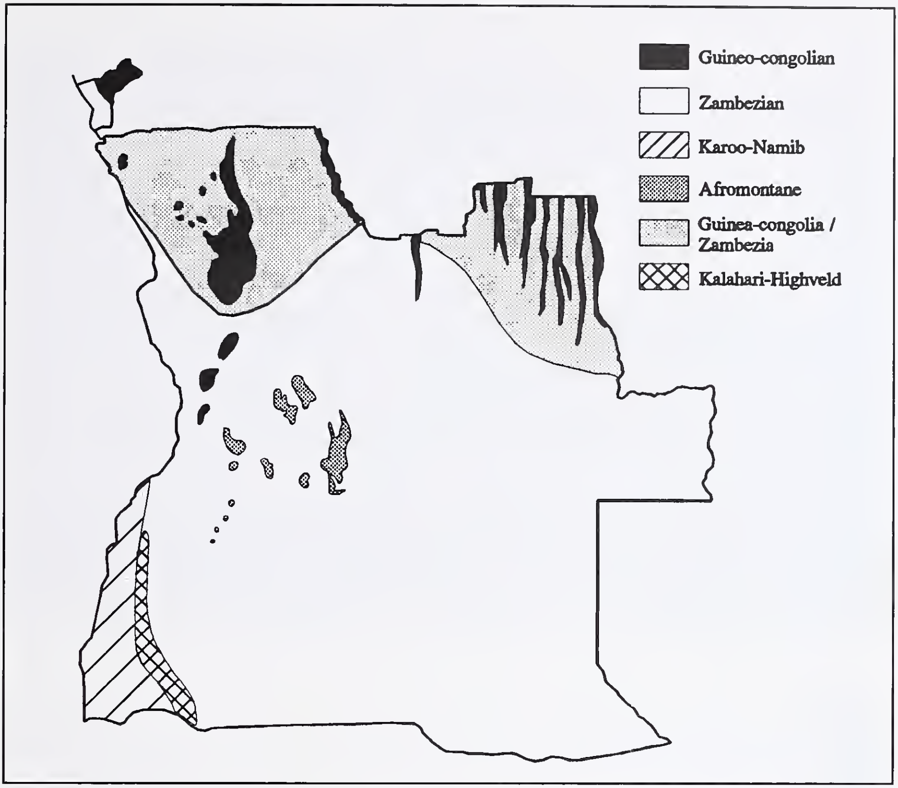

Figure 1.—Major chorological divisions of Angola (after White 1983).

VEGETATION

Barbosa (1970) provides a valuable map of the vegetation of Angola at a scale of 1: 2 500 000. The map is based on the pioneer work of Gossweiler & Mendonça (1939) but benefitted from the detailed knowledge of the genus *Brachystegia* which Barbosa acquired during more than 15 years of field work in Angola. Barbosa (1970) recognizes 32 main vegetation types and describes over 100 subordinate types. In view of the absence of any description of Angolan vegetation in the English language since Airy Shaw's (1947) summary of Gossweiler & Mendonça (1939) and Teixeira's (1968b) notes on the vegetation, a brief outline of major vegetation types is considered appropriate in this paper. The description will refer to the various Barbosa (1970) vegetation types found within the framework provided by White's (1983) phytochoria.

Guineo-Congolian regional centre of endemism

This region is represented in Angola by evergreen and semideciduous forests, forest-savanna mosaics and gallery forests in the northwestern and northeastern extremes of the country. These communities occupy the escarpment slopes and well dissected regions of the interior plateau, ranging from 200 to over 1 400 m altitude and receiving from 1 200 to 1 800 mm rainfall per annum. Depauperate outliers of this region are to be found in isolated forest patches extending southwards along the Angolan escarpment.

Three of Barbosa's vegetation types (1, 2 and 3) fall into this phytochorion. Evergreen equatorial rainforest is found in the interior of Cabinda, where specimens of *Gilletiodendron ogoouense*, *Tetraberlinia bifoliolata*, *Julbernardia seretii*, *Librevillea klainei*, etc. reach heights of 30 to 50 m (Figure 2). This forest is surrounded by more extensive areas of partially deciduous communities, with *Gossweileriodendron balsamiferum, Oxystigma oxyphyllum*, *Pentaclethra eetveldeana*, *Terminalia superba,* etc.

To the south of the Zaïre River in the Zaïre, Uige, Kwanza Norte and Kwanza Sul provinces, extensive forests comprising many deciduous species are found. These 'coffee forests' receive from 1 000 to 1 800 mm rainfall per annum, with two to three rainless months. The forests occupy the upper slopes of the western escarpment and benefit from an almost continuous stratus cloud cover resulting

Figure 2.—Guineo-Congolian rainforest in Cabinda.

Figure 3.—A tongue of Guineo-Congolian gallery forest penetrating *Brachystegia* woodlands and

from the influence of the cold Benguela Current. Dominant trees include *Celtis prantlii*, *C. mildbraedii*, *Morus mezozygia*, *Albizia glaberrima*, few of these exceeding heights of 30 m.

Guinea-Congolia/Zambezia regional transition zone

Surrounding the extensive rainforests are vast areas of tall grasslands interspersed by gallery forests in the valleys and isolated forest patches on ridges and plateaux (Figure 3) (Barbosa types 7, 8, 9 and 10). The forests, 20 to 40 m in height, include many of the species noted in the previous grouping, with species such as *Piptadeniastrum africanum, Chlorophora excelsa, Ceiba pentandra, Musanga cecropioides, Allanblackia floribunda, Entandrophragma angolensis*, etc. The grasslands, 2 to 4 m high, include various species of the genera *Hyparrhenia, Andropogon, Pennisetum, Loudetia, Panicum*, etc. Trees and shrubs are sparsely scattered through this grassland as their survival requires considerable capacity to resist the intense fires which pass through the grassland annually. Typical woody species are *Hymenocardia acida, Erythrina abyssinica, Piliostigma thonningii, Cussonia angolensis*, etc.

Further south, this rather heterogeneous grouping (Barbosa types 13 and 22) includes a variety of communities occupying well-drained, rolling hills at 800 to

1 200 altitude and receiving 1 100 to 1 500 mm rainfall per annum. The communities are generally more open than those of the *Brachstygia* formations, lack members of that genus and furthermore lack the typical miombo catena of wooded ridges and grassy valleys. Trees include *Cussonia angolensis*, *Entadopsis abyssinica*, *Combretum* spp., *Cochlospermum angolensis*, *Sterculia quinqueloba*, etc., while the grasses include *Hyparrhenia* spp., *Andropogon* spp. and *Panicum maximum*.

Zambezian regional centre of endemism

This centre occupies over 80% of Angola. The vegetation structure ranges from tall dry forest to open, treeless edaphic grasslands, but by far most of the country is typical miombo woodland.

Dry deciduous woodland with abundant *Baikiaea plurijuga* (Barbosa type 25) occupies a vast area of the extreme southeast of Angola (Cuando-Cubango province). The formation is almost entirely restricted to sandy substrates and penetrates the *Colophospermum mopane* formation to as far west as the Ruacana Falls, at 14°06′E. Pure stands of *Baikiaea plurijuga* are rare. The species is most typically associated with *Guibourtia coleosperma*, *Pterocarpus angolensis*, *Burkea africana*, *Dialium englerianum*, with local communities of

Figure 4.—Tall woodlands of *Guibourtia coleosperma*, *Burkea africana* and *Baikiaea plurijuga* on Kalahari sands, Cuando-Cubango province.

Figure 5.—Typical miombo woodland dominated by *Brachystegia spiciformis* with intervening drainage line grasslands, Bikuar National Park, Huila province.

Ricinodendron rautanenii (Figure 4). The woody species range from 5 to 12 m in height. Grasses are sparse and wiry, up to 1.5 m tall and include *Aristida stipitata, Triraphis schlecteri, Tristachya rehmannii*, etc.

Dry forests and woodlands on Kalahari sands (Barbosa types 4, 16 and 17) with *Marquesia macroura, Guibourtia coleosperma* and *Cryptosepalum pseudotaxus* are either locally dominant or in some areas form distinctive and extensive communities. *Cryptosepalum* dry forest is found on the eastern border adjoining the Balovale district of Zambia.

Typical miombo woodland (Barbosa types 16, 17, 18 and 24) occupies approximately 47% of the country's surface area. *Julbernardia paniculosa* and *Brachystegia spiciformis* are widespread throughout, and *B. floribunda, B. boehmi, B.wangermeeana* and *B. gossweilerii* locally dominant (Figure 5). The woodlands range from 4 to 12 m in height, with a sparse to moderate grass and shrub layer below the continuous canopy. Drainage-line grasslands are typically dominated by *Loudetia simplex* and members of the tribe Andropogoneae.

A mosaic of mixed communities occupy the lower (100 to 500 m), drier (600 to 1 000 mm) slopes of the western escarpment and the littoral zone (Barbosa types 11, 14, 22 and 23). Dense dry thicket and scrub forest are the typical physiognomies, with *Sterculia setigera, Adansonia digitata, Euphorbia conspicua,*

Strychnos spp. and *Acacia welwitschii* dominant in the woody strata. Grasslands between the closed communities are dominated by *Andropogon gayanus, Heteropogon contortus* and *Hyparrhenia* spp. Extensive sand plateaux within this formation, especially along the littoral, are occupied by *Hyphaene gossweileri* palm savanna, with *Eragrotis superba*, *Schizachyrium semiberbe* and *Digitaria milanjiana*.

Also included here is the vast Baixa de Cassange, an area geographically isolated from the western escarpment and coastal zones but sharing many floristic and ecological characteristics.

Mopani woodland is well represented in southwestern Angola. A wide range of communities are found, from pure stands of *Colophospermum mopane* up to 10 m high, to mixed associations of this species with *Terminalia prunioides, Spirostachys africanus, Acacia erubescens, Balanites angolensis*, etc. In common with its habitat elsewhere in Africa, mopane occurs almost exclusively on clayey and rocky substrates, giving way to *Baikiaea plurijuga* communities on the sands to the east and to *Brachystegia* formations in higher, moister areas.

Edaphic grasslands (Barbosa type 12) occupy much of the Lunda Norte and Lunda Sul provinces in the extreme northeast of Angola. Called ‘chanas de borracha’ by Gossweiler & Mendonça (1939), these extensive treeless plains are characterized by the abundance of *Landolphia parvifolia* var. *thollonii*, a perennial shrub with robust subterranean organs and copious rubbery latex.

A rather remarkable grassland (Barbosa type 23) occurs in an extensive area to the north and south of Luanda. The community occupies smoothly rounded hills of Miocene and Oligocene marine sediments comprising highly plastic montmorillonite-rich clays and marls. The outstanding feature of this is the complete dominance, virtually to the exclusion of any other species, of *Setaria welwitschii*. This grass forms extremely dense swards 1 to 1.5 m high, sometimes covering continuous areas of up to 100 000 hectares.

Kalahari-Highveld regional transition zone

White (1983) shows a narrow tongue of this transition zone penetrating into Angola between the Namib Desert and the escarpment. This approximates with Barbosa’s type 27—sublittoral shrublands with *Acacia, Commiphora, Colophospermum, Aristida,* etc. Although occupying a vast area in Namibia, Botswana and South Africa, this phytochorion has little significance in Angola.

Karoo-Namib regional centre of endemism

The Karoo-Namib region can be roughly delimited in Angola by the 200 mm isohyet, falling in the extreme southwestern corner of the country. Here desert conditions prevail with a very sparse flora of which *Welwitschia mirabilis* is characteristic.

Vegetation included here (Barbosa types 27 and 28) ranges from sparse perennial grasslands and herbaceous communities of subdesert sand and gravel plains to dense thickets on the arid hill and mountain country. The sandy plains are occupied by *Aristida prodigiosa, Danthoniopsis dinteri, Tetrapogon tenellus* etc. (Figure 6), while the gravel plains are particularly important as the preferred habitat of *Welwitschia mirabilis* which occurs here in much greater abundance than anywhere south of the Cunene (Figure 7).

The arid savanna and thicket communities include several *Acacia* species—*A. reficiens, A. detinens, A. mellifera, A. tortilis*, plus several *Commiphora* and *Boscia* species, and *Terminalia prunioides, Catophractes alexandri, Rhigozum brevispinosum, Sesamothamnus benguellensis, Colospermum mopane* etc. (Figure 8). These woody communities seldom exceed a height of 4 m; only along the dry river beds, called 'mulolas', do trees reach any stature—here *Acacia erioloba, A. albida* and *Combretum imberbe* of 15 m and more are found.

The nearly vegetationless mobile dunes of the Angolan Namib (Barbosa type 29) occupy approximately 4 400 km^2, lying between the Cunene and Curoca Rivers. The sparse vegetation that is found on the few temporarily stabilized dunes include *Stipagrotis sabulicola, Odyssea paucinervis* and *Acanthosicyos horrida.*

Figure 6.—Intermontane basin of grassy plains with *Acacia erioloba* and *A. tortilis*, and mountains covered with *Colophospermum mopane, Acacia* spp., *Commiphora* spp., etc. Iona National Park, Namibe province.

Figure 7.—*Welwitschia mirabilis* community on the gravel plains of Iona National Park, Namibe province.

Afromontane archipelago-like regional centre of endemism

Relic forest patches representing this region are restricted to a few isolated valleys in the west-central highlands of Angola, where *Podocarpus milanjianus* is locally dominant above 2 000 m. The avifauna of these forests is of considerable interest, including numerous subspecific endemics and very strong affinities with the avifauna of other remote Afromontane forests (Huntley 1974a, 1978).

The small and scattered relics of *Podocarpus milanjianus* forest (Barbosa type 6) in Angola are of tremendous phytogeographic interest yet remain to be explored by botanists. Patches of this type seldom exceed 20 hectares in area, are restricted to the deep ravines or remote valleys of the highest mountains in the Huambo and Kwanza Sul provinces, and are almost certain to disappear completely unless drastic conservation efforts are implemented. The most extensive forests, at Mt Namba, were exploited for timber during the colonial period and are devoid of any pristine patches. Relatively undisturbed examples occur in the steep valleys of Mt Moco, lying between 1 800 and 2 400 m altitude (Figure 9).

Trees recorded from these remnant patches include *Podocarpus milanjianus, Polyscias fulva, Apodytes dimidiata, Pittosporum viridiflorum, Syzygium*

guineense subsp. *afromontanum* and *Halleria lucida*. The forests receive between 1 200 and 1 800 mm rainfall annually and are not as heavily festooned with epiphytes as are similar communities elsewhere in Africa. The forests seldom exceed a height of 8 m and the canopies are usually very irregular due to the steep gradients on which the patches are located.

Further south, the relic Afromontane forests occur in a mosaic of undifferentiated montane communities (Barbosa type 5) on the Serra de Chela of Huila province where pockets of *Podocarpus milanjianus* forest survive in deep humid ravines and on isolated peaks at altitudes above 1 800 m. Open grasslands with widely scattered trees and shrubs (Barbosa type 32) cover large areas of the Angolan highland plateau at altitudes above 1 600 m in the Huambo, Bié and Kwanza Sul provinces. Included here are the grasslands of seasonally waterlogged plateaux where *Parinari capensis, Myrsine africana, Protea welwitschii, Dissotis canescens, Cyathea* sp., *Loudetia* spp., *Fimbristylis* spp. and *Xyris* spp. number amongst the constituents. Better drained areas include *Philippia benguelensis, Protea trichophylla, Stoebe vulgaris, Cliffortia* sp., *Themeda triandra, Tristachya inamoena, T. bequertii, Hyparrhenia andogensis, H. quarrei, Monocymbium ceresiforme, Ctenium* sp., etc.

Figure 8.—Sand dunes and marble outcrops with *Commiphora* sp., *Acacia* sp., *Stipagrostis* sp., etc. Iona National Park, Namibe province.

Azonal vegetation types

In addition to the various plant communities that can be easily related to White's phytochoria, two major azonal ecosystems are of importance in Angola: mangroves and swamps.

In contrast to the situation on the east coast of Africa where mangrove communities are found as far south as 32°10′ latitude, the cold Benguela Current flowing northwards along Angola's coastline results in this tropical formation disappearing south of Lobito, at only 12°20′S. The mangroves at Lobito have been drastically reduced by harbour development and the southernmost example of this vegetation type still to be found in almost pristine condition is that at the mouth of the Kuvo River at 10°50′S. Other fine examples are to be found at the mouths of the Longa, Kwanza, Dande, M'Bridge, Zaïre, Chiluango and Massabi Rivers, the most extensive being at the Zaïre mouth.

Figure 9.—Relic patch of Afromontane forest on Mt Moco, Huambo province. The forest, including *Podocarpus milanjianus, Pittosporum viridiflorum, Halleria lucida,* etc., is surrounded by grasslands with scattered *Protea* spp., *Philippia benguelensis, Cliffortia* sp., etc.

Recent and positive identification of Angolan mangrove species is still wanting but it appears that *Rhizophora racemosa, R. harrisonii, R. mangle* and *Avicennia africana* are all present in the more northerly river mouths. Behind and upstream from the mouths dense thickets of *Chrysobalanus ellipticus, Drepanocarpus lunatus, Dalbergia ecastaphyllum, Leguncularia racemosa, Hibiscus tiliaceus,* etc. occur. Of special interest in some of the estuaries is the presence of dense communities of *Raphia gossweileri*, occupying permanently waterlogged banks and islands dissected by the main waterways.

Extensive communities of *Cyperus papyrus* are found in the floodplains of all the larger rivers north of the 13° south latitude. This type is particularly well developed in the lower floodplains of rivers Kwanza and Longa. The margins of the communities are occupied by *Typha capensis, Echinochloa stagnina* and *Phragmites mauritianus*. Similar but much less extensive examples of this swamp type are found in some of the floodplains of the interior, especially in the Moxico and Cuando-Cubango provinces.

VEGETATION CONSERVATION

Nature conservation legislation in Angola was first consolidated by the Portuguese colonial administration in 1955 by Decreto 40040 which established the principles on which the conservation of soil, flora and fauna is based (Angola 1955).

Although the conservation of flora and vegetation during the colonial period was nominally the responsibility of the then Directorate of Agriculture and Forestry, in practice this organization only regulated timber exploitation. Many so-called forest reserves were in fact merely areas in which the Forestry Department reserved the right to grant or terminate timber concessions. Unfortunately little regard was shown in terms of conservation of the whole forest flora, or reafforestation of those species extracted. Any forest reserve that contained timber of commercial value was almost invariably made available to concessionaires, or simply deproclaimed, as was the case with the Kaconga and Alto Maiombe Forest Reserves of Kabinda, both of very great biological interest (Huntley 1973a).

Conservation of vegetation in the true sense could only be achieved in the national parks and reserves which fell under the control of the Directorate of Veterinary Services. These protected areas totalled over 68 000 km^2 yet very few were free from serious disturbing factors prior to Independence in 1975. As discussed below, the situation has in most respects deteriorated considerably since Independence.

While these seemingly overwhelming problems are indeed a very great challenge to the country's conservationists, there still remain, within these huge parks and reserves, vast areas of pristine vegetation. Even Kisama, one of the parks worst affected by human activities, still has undisturbed examples of 10 000 to 50 000 ha of nearly all major vegetation types.

From Table 1 it will be noted that only the Karoo-Namib and Zambezian centres are well represented in present protected areas. This situation is a direct consequence of the traditional policy of creating national parks and reserves for the sole or primary object of protecting certain larger mammal species, neglecting biologically unique ecosystems possessing less spectacular faunas. This policy is currently being changed in Angola and attempts are being made to proclaim conservation areas in all major ecosystems following the recommendations of Huntley (1974b). As a base to these programmes, an analysis was made of the

TABLE 1.—List of National Parks, Strict Nature Reserves, Partial Reserves and Regional Nature Parks of Angola. Centres of endemism follow White (1983); vegetation types according to Barbosa (1970)

Name	Area (km^2)	Status	Date established	Centre of endemism	Vegetation types
Iona	15 920	National Park	1937	Karoo-Namib	21, 27, 28, 29
Kameia	14 000	National Park	1938	Zambezian	17, 31
Kisama	9 960	National Park	1938	Zambezian	11, 23, 30
Luando	8 280	Strict Nat. Res.	1938	Zambezian	17, 18
Bikuar	7 900	National Park	1938	Zambezian	15, 18
Mupa	6 600	National Park	1938	Zambezian	15, 18, 20
Namibe	4 680	Partial Reserve	1957	Karoo-Namib	27, 28
Kangandala	600	National Park	1963	Zambezian	18
Chimalavera	160	Regional Park	1972	Karoo-Namib	27

conservation status of all vegetation types in Angola. For this survey, Barbosa's map was used and the area of each of his major types calculated. The percentage of each type falling within existing conservation areas was similarly determined. The results (Table 2) illustrate the very uneven cover provided Angolan vegetation types.

Of the 32 vegetation types described by Barbosa, only 11 are represented within existing protected areas. The disparity of the protection afforded the major phytochoria is alarming. The Karoo-Namib region, represented by vegetation types 28 and 29 which occupy 1.1% of the country's land surface, has 81% of its area protected, while the Guineo-Congolian region, comprising 10.7% of Angola's total area, is unrepresented in any protected area. The relic Afromontane *Podocarpus* forests, without doubt the most seriously threatened of all ecosystems in Angola, are also without protection. It is therefore evident that conservation efforts should be directed towards the creation of parks and reserves within examples of these two regional centres of endemism.

The urgent need for the establishment of a Strict Nature Reserve in the Maiombe Forest of Cabinda was one of the principal recommendations of the 'Reuniao para o Estudo dos problemas da Fauna Selvagem e proteccao da Natureza no Ultramar Portugues' held in Lubango in November 1972. Detailed proposals for the proclamation of the reserve (Huntley 1973a) have not been implemented. If established, the reserve would provide for the protection of examples of Barbosa's vegetation types 1 and 2 which are the most typical representatives of the Guineo-Congolian region in Angola.

Further reserves in examples of this region are needed in the Kwango, Luachimo and Luia valleys and in the Gabela Mountains. These areas include Barbosa's types 3, 8 and 12. The survey and selection of suitable protected areas in types 5, 7, 9, 10 and 14 (all of Guineo-Congolian affinities) are still to be initiated.

TABLE 2.—Vegetation types of Angola, after Barbosa (1970), indicating the present area of each type falling within protected areas

Type No.	Physiognomic type & moisture regime	Typical genera	Phytogeographic affinities	Total area (km^2)	Protected area (km^2)	%of total area	Protected areas
1.	Forest, humid, evergreen	*Gilbertiodendron, Tetraberlinia*	Guineo-Congolian	481	0	0	–
2.	Forest, humid, semideciduous	*Gossweilerodendron, Oxystigma*	Guineo-Congolian	3 765	0	0	–
3.	Forest, humid, semideciduous	*Celtis, Albizia*	Guineo-Congo./Zamb.	20 989	0	0	–
4.	Forest, dry, semideciduous	*Cryptosepalum*	Zambezian	2 163	0	0	–
5.	Forest, humid, semideciduous	*Newtonia, Parinari*	Zamb./Guineo-Congo.	160	0	0	–
6.	Forest, humid, semideciduous	*Podocarpus*	Afromontane	10	0	0	–
7.	Forest/savanna mosaic, humid	*Piptadeniastrum, Bosqueia*	Guineo-Congolian	13 699	0	0	–
8.	Forest/savanna mosaic, humid	*Marquesia, Berlinia*	Guineo-Congolian	79 631	0	0	–
9.	Forest/savanna mosaic, humid	*Celtis, Hyparrhenia*	Guineo-Congo./Zamb.	27 798	0	0	–
10.	Forest/savanna mosaic, mesic	*Allanblackia, Entandrophragma*	Guineo-Congo./Zamb.	11 456	0	0	–
11.	Forest/savanna mosaic, mesic	*Pteleopsis, Adansonia*	Zambezian	14 900	745	5	Kisama
12.	Thicket/savanna mosaic, humid	*Landolphia*	Zambezian	46 705	0	0	–
13.	Thicket/savanna mosaic, humid	*Annona, Piliostigma*	Zambezian	27 798	0	0	–
14.	Thicket/savanna mosaic, mesic	*Crossopteryx, Heteropogon*	Zamb./Guineo-Congo.	12 497	0	0	–
15.	Woodland/thicket mosaic, mesic	*Baikiaea, Ricinodendron*	Zambezian	16 422	9 497	72	Bikuar, Mupa
16.	Woodland, humid	*Julbernardia, Brachystegia*	Zambezian	138 754	0	0	–
17.	Woodland, humid	*Brachystegia, Marquesia*	Zambezian	224 393	1 882	3	Luando, Kameia
18.	Woodland, humid	*Brachystegia, Julbernardia*	Zambezian	74 333	7 693	26	L, B, Kangandala
19.	Woodland, mesic	*Brachystegia*	Zambezian	5 367	0	0	–
20.	Woodland, mesic	*Colophospermum*	Zambezian	69 777	3 551	5	Iona, Mupa
21.	Woodland, mesic	*Colophospermum, Acacia*	Zambezian	8 332	0	0	–
22.	Savanna-woodland, humid	*Cochlospermum, Combretum*	Zambezian	27 718	0	0	–
23.	Thicket/savanna mosaic, arid	*Adansonia, Sterculia*	Zambezian	21 951	9 028	41	Kisama
24.	Woodland/savanna mosaic, mesic	*Brachystegia, Burkea*	Zambezian	114 560	0	0	–
25.	Savanna-woodland, mesic	*Baikiaea, Guibourtia*	Zambezian	60 324	0	0	–
26.	Savanna-woodland, mesic	*Adansonia, Peucedanum*	Zambezian	108 231	0	0	Namibe
27.	Savanna/grassland mosaic, arid	*Acacia, Commiphora*	Zamb./Karoo-Namib	35 570	9 056	27	Iona, Namibe, Chim.
28.	Grassland/shrubland, subdesert	*Aristida, Welwitschia*	Karoo-Namib	9 934	7 311	74	Iona, Namibe
29.	Desert	*Odyssea, Acanthosicyos*	Karoo-Namib	4 406	4 406	100	Iona
30.	Swamp	*Cyperus, Typha*	Zambezian	1 362	186	14	Kisama
31.	Grassland, floodplain	*Loudetia*	Zambezian	49 990	14 024	31	Kameia
32.	Grassland, montane	*Protea, Stoebe*	Zamb./Afromontane	12 898	0	0	–

Interest in the relic Afromontane forests of Moco and Namba was first stimulated by the discovery of their rare and endemic avifaunas nearly 60 years ago. Unfortunately very little attention has been paid to these areas by botanists, and the status of the remaining forest patches is rapidly deteriorating due to excessive burning and felling. Proposals for the creation of a Strict Nature Reserve at Mt Moco and a Regional Nature Park at Tundavala are needed. These areas would protect examples of vegetation types 6 and 32.

The vegetation types of Angola within the Zambezian centre are reasonably well conserved. Of the 24 types which include Zambezian constituents, nine are presently protected while five of the remaining types fall within Reserves and Natural Monuments proposed two decades ago (Huntley 1974b). The eight vegetation types which have to be studied include several (4, 5 and 19) with important faunal communities besides their phytogeographic interest, and deserve priority treatment.

The extremely favourable conservation status of the Karoo-Namib vegetation types of Angola has been noted above. The Angolan Namib (type 29) falls wholly within the limits of Parque Nacional de Iona, while 74% of type 28 falls within this Park and the Reserva Parcial do Namibe. Vegetation type 27, which has both Karoo-Namib and Zambezian affinities is also well protected in these conservation areas and in the Parque Regional Natural da Chimalavera.

The maritime and estuarine ecosystems of Angola are in need of detailed study before proposals can be made for their conservation. Mangrove systems are offered protection in Parque Nacional da Kisama (Rio Kwanza and Rio Longa), but the richest intertidal communities apparently fall outside the limits of this Park and of Iona, whose combined sea shores total over 270 km.

FLORA PROTECTION

The protection of individual species of plants in Angola has not yet been provided for by legislation. Commercial timber extraction can only be undertaken by concession holders, but although limits are set on the volume of individual species which may be felled, the regulations were formulated on a basis of commercial timber exploitation and are impractical in terms of ecosystem or flora conservation.

Species, genera and families such as *Welwitschia mirabilis, Encephalartos* and Orchidaceae, which merit rigorous protection, are safe only within parks and reserves. Fortunately very few people in Angola demonstrate any interest in cultivating indigenous plants, and the fashionable hobby of *Aloe* or cycad collecting which has so seriously threatened these taxa in other southern African countries has not yet reached Angola. The formulation of suitable flora protection legislation is severely handicapped by the extremely rudimentary knowledge presently available on the distribution and status of most species. The selection of taxa qualifying for special protective measures cannot yet be made on the basis

of adequate field information. Furthermore, the inability of the conservation authorities to enforce well defined game laws makes the promulgation of detailed flora protection legislation of doubtful advantage. Current efforts should be directed towards the prevention or control of the commercialization and export of rare plants rather than attempting to protect them against casual amateur collectors or traditional medical practitioners.

THE IMPACTS OF ANGOLA'S CIVIL WAR ON BOTANICAL DIVERSITY

For 20 years, Angola has experienced an almost continuous, intense conflict that at some point in the period has affected every town and inhabitant in all but the most isolated rural areas.

According to the UNDP's scale of 'quality of life' for 1992, Angola was already 139th out of 160 countries worldwide. And this was its position before the outbreak of postelection war, which has wrought more havoc in a year than in all the previous years together and continues to kill, either in direct conflict, or from hunger and disease, an estimated 1 000 people a day—mostly civilians. It is estimated that some two million people (nearly one fifth of the total population) are displaced within the country.

The impact of the prolonged war on the fauna of Angola has been catastrophic. A detailed survey of the distribution and status of 80 species of larger mammals in Angola (Huntley 1973b) was followed in 1992 by a rapid assessment of their status (Huntley & Matos 1992) which concluded that few if any viable populations of the larger mammals survive even in the largest protected areas such as Kisama and Iona. They estimated that 21 species of larger mammals, including gorilla, chimpanzee, lion, cheetah, manatee, elephant, black rhinoceros, giraffe and giant sable, had been reduced to the threshold of extinction, if they are not already extinct in Angola.

As far as botanical diversity is concerned, there have been both negative and positive results in the post-Independence period.

On the negative side:

- First and foremost, the protected areas that existed at the time of Independence (1975) have been left effectively unprotected for longer or shorter periods, as park wardens left the areas for economic or security reasons; the whole warden network became either unworkable and/or of no priority, and was therefore gradually reduced to insignificance. The former protected areas became open spaces for poachers, commercial timber felling, human settlement and cultivation.

- The breakdown in the distribution of fuel supplies has forced more and more people to turn to biomass for firewood and charcoal, a practice particularly destructive in areas near urban centres. This has also been

a major contributory factor in the desertification of semi-arid zones of southern coastal areas of the Benguela and Namibe provinces.

- There is a crippling shortage of skilled human resources in all fields, at all levels and in all institutions. In the botanical field, and confronted with a vast potential wealth of plant resources, there is not a single Angolan professional systematic botanist working in the country.

  There are three herbaria in Angola, in Huambo (with 40 000 specimens), Lubango (with 10 000 specimens) and Luanda (35 000 specimens), but none with a professional botanist as curator. The most important of the three, in Huambo, was maintained in good condition for 16 years after Independence, mainly due to the efforts of the late Eng. Fernando Marcelino, as Director of the Agricultural Research Institute and Chairman of the National Plant Genetic Resources Committee. The herbarium, repaired in 1992, has once again been damaged in the increased conflict in the region.

On the positive side:

- Unlike the large mammal populations and excepting certain timber and firewood species in specific areas, most plant populations, both in and out of protected areas, have benefitted from being abandoned. Large areas of former coffee plantations have reverted to secondary forest cover. In general the state of the vegetation in most areas has improved since Independence.

- As far as crop plant diversity is concerned, as a result of the breakdown in circulation and trade over wide areas of the country, farmers have been forced to rely on their own local crop varieties for subsistence. This has meant that these crops have been kept in an enforced state of *in situ* conservation.

- Angola is part of the SADC Regional Genebank network, which has provided valuable regional contacts and specialist PGR training. There are now four people working directly in PGR conservation in Angola.

- The total population of Angola is estimated at around 11 million, and the density in rural areas is very low. Over a quarter of the country has a population density of less than 1 person per km^2 and half of the country of less than 5 people per km^2 (In other words, there are some half a million km^2 of territory hardly affected by human presence at the moment.)

CONSERVATION PRIORITIES FOR ANGOLA'S BOTANICAL RESOURCES

In 1992 a 10-week study was undertaken of the environmental situation in Angola (IUCN 1992) which identified a number of urgent priorities for action. The

study was undertaken during the brief period of peace which preceded the elections of September 1992 which were followed by an escalation of civil war. The recommendations have nevertheless led to some action, while response to the broader recommendations will have to await the resolution of the political situation. Some of the recommendations are outlined here.

Appropriate national legislation must be promulgated whereby protected areas are evaluated and reclassified and new areas established following the recommendations presented by Huntley (1974b). The expanded network (Figure 10, Table 3) would increase the existing network by 15.5%, bringing the total protected area network in Angola to 78 644 km^2 or only 6.3% of the country. The network would substantially increase the effectiveness of the present system by including representative examples of all the phytochoria, vegetation types and ecosystems currently missing from the protected area system.

- With regard to faunal protection, a start has been made with the recent (1993) introduction of laws prohibiting the export of live animals such as parrots and monkeys, and of ivory and turtle shells. An IUCN/Ministry of Agriculture and Rural Development project has begun to train demobilized soldiers as park wardens, and some of these are already in place.

- Angola is a signatory to the Convention on Biological Diversity. It is a member of the FAO Plant Genetic Resources Commission and will sign the International Undertaking on Plant Genetic Resources. National legislation on the collection and transfer of Plant Genetic Resources is also under consideration.

- Another urgent priority is the training of conservation personnel to identify vegetation types, to recognize species, to curate herbaria, to handle data, to plan and execute conservation projects, etc. A few graduates have been sent to Portugal for short-term herbarium training under Portuguese specialists in Angolan vegetation.

- There is an acute shortage of copies of essential reference works on Angolan vegetation, including those of Barbosa (1970), Gossweiler & Mendonça (1939), Gossweiler (1953) and Diniz (1973), which need to be reprinted.

- Support is also needed for a search and review of existing literature and information dealing with Angolan biodiversity, in Angola, Portugal and other countries.

- It is essential to increase public awareness of the long-term benefits to be gained from the conservation of biodiversity, and it is particularly important for local populations to be involved in, and benefit directly from, conservation projects if there is to be any hope of these having lasting effects.

- A State Secretariat for the Environment was established in 1992 and some progress has been made in both governmental and non-governmental circles, partly as a result of increased media coverage of conservation issues.
- The establishment of southern African regional links would be of mutual benefit, for sharing information, for exchange purposes and for joint conservation projects of vegetation types across national borders.

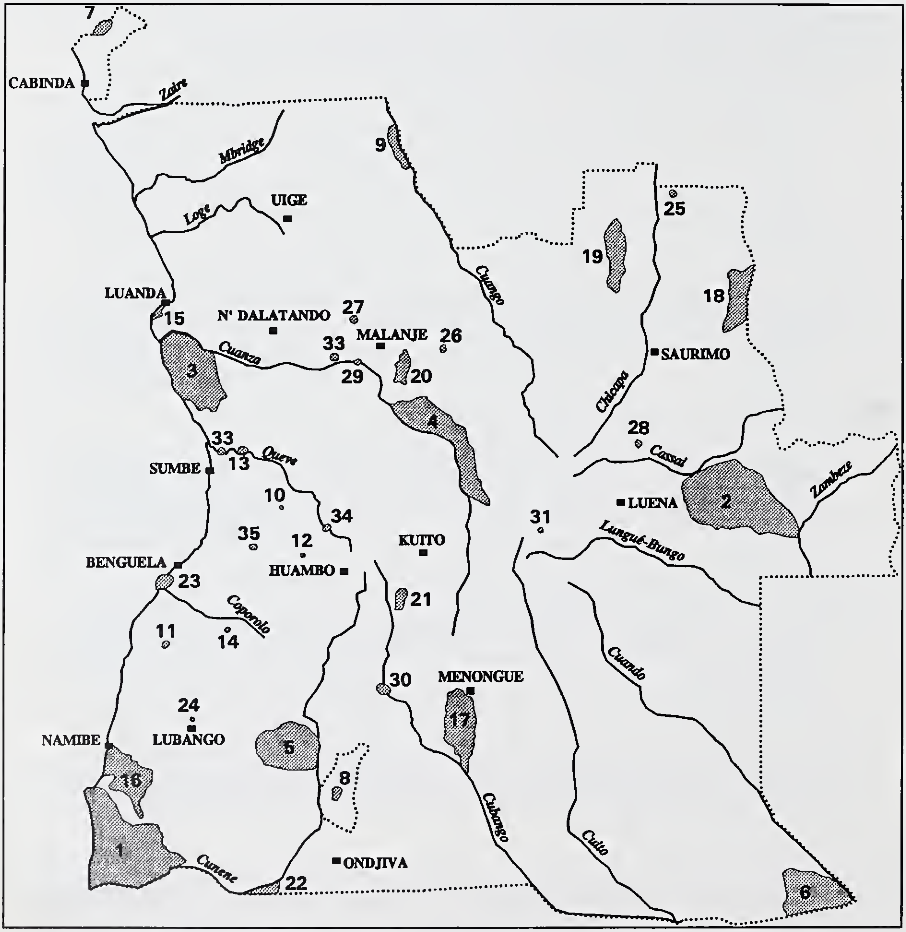

Figure 10.—The distribution of existing and proposed protected areas. Numbering follows Table 3 (after Huntley 1974b).

TABLE 3.—List of existing and proposed protected areas

Name and recommended classification	Area (km^2)	Chorological division
1. Iona NP	15 920	Karoo-Namib
2. Kameia NP	14 000	Zambezian
3. Kisama NP	9 960	Zambezian
4. Luando NP	8 280	Zambezian
5. Bikuar NP	7 900	Zambezian
Mupa NP	6 600	Zambezian
6. * Luiana SNR	3 000	Zambezian
7. * Maiombe SNR	400	Guineo-Congolian
8. * Mupa SNR	150	Zambezian
9. * Cuango SNR	100	Guineo-Congolian
10. * Namba SNR	100	Afromontane
11. * Serra de Neve SNR	80	Karoo-Namib/Zambezian
12. * Monte Moco	60	Afromontane
13. * Gabelo SNR	50	Guinea-Congolia/Zambezia
14. * Chongoroi SNR	20	Guinea-Congolia/Zambezia
15. * Ilha dos Passaros SNR	10	–
16. Namibe RNP	4 684	Karoo-Namib
17. * Cuelei RNP	4 500	Zambezian
18. * Luia RNP	1 500	Guinea-Congolia/Zambezia
19. Carumbo RNP	1 500	Guinea-Congolia/Zambezia
20. Kangandala RNP	600	Zambezian
21. * Cutato RNP	300	Zambezian
22. * Ruacana RNP	200	Zambezian
23. Chimalavera RNP	160	Karoo-Namib
24. * Tundavala RNP	40	Afromontane/Zambezian
25. * Luachimo RNP	20	Guinea-Congolia/Zambezia
26. * Tala Mungongo NM	30	Guinea-Congolia/Zambezia
27. * Quedas do Calandula NM	10	Guinea-Congolia/Zambezia
28. * Dala NM	10	Zambezian
29. * Salto do Cavalo NM	10	Zambezian
30. * Cutato NM	10	Zambezian
31. * Luando NM	10	Zambezian
32. * Binga NM	10	Zambezian
33. * Pungo Andongo NM	20	Zambezian
34. * Alto Hama NM	20	Zambezian
35. * Monte Belo NM	10	Zambezian

NP = National Park; SNR = Strict Nature Reserve; RNP = Regional Nature Park; NM = Natural Monument.
* indicates a proposed new conservation area.

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The paper is dedicated to the memory of two great Angolans, Engenheiro Fernando Marcelino and Dr David Bernardino, assassinated by Unita in 1992. Their life-long commitment to the development of agricultural and health services in Angola, their warm hospitality and encouragement to the authors of this paper, and their absolute faith in democracy and justice will be remembered with fondness and respect by all who knew them.

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Botanical diversity and its conservation in Lesotho

S. TALUKDAR
National University of Lesotho, P.O. Roma 180, Lesotho.

ABSTRACT

Lesotho's plant species include relicts from different past climatic and topographic conditions, while on a different time scale others have become rare and endangered through recent human activities. The introduction of exotic plant species and the changes in agricultural patterns have also had an impact on the floristic make-up of Lesotho.

The Lesotho Highlands Water Project is a massive water transfer scheme now under construction in the mountains of Lesotho. The main tributaries of the Senqu or Orange River will be diverted in the project area into the Vaal catchment in order to supply the water needs of the highly industrialized Witwatersrand complex in South Africa. Building the infrastructure for an undertaking of this magnitude has invariably led to disturbances in a mountain region with a high degree of endemism.

INTRODUCTION

The origin and development of the flora of southern Africa have been the subject of several reviews, notably those by Plumstead (1969), Axelrod & Raven (1978), Van Zinderen-Bakker (1978), Goldblatt (1978) and White (1983). Lesotho occupies a well-defined niche in the region, bounded on the east by the summit of the high-altitude plateau which rises steeply from the Indian Ocean side of the subcontinent, encompassing several major mountain ranges before merging on its western boundary with the plains of the Orange Free State.

The present topography of Lesotho is the result of tectonic and climatic changes over extensive periods. More recently, the advent of human settlement has accelerated the pace of change. As a result, some of the plant species we now see are relicts of extinct floras that have disappeared through climatic and topographic changes, as well as through human activity.

NONFLOWERING PLANTS

Bryophytes

The fossil records of bryophytes, though far from extensive, indicate that the two broad groups, liverworts and mosses, were already differentiated by the end

of the Palaeozoic era. Possibly the liverworts evolved earlier (Watson 1964). Lesotho is of great attraction to bryologists. Several new records have been reported by Magill (1987), Lewinsky & Van Rooy (1990), Van Rooy (1991, 1992), and Meakins & Duckett (1993). As Magill (1987) states, 'the Drakensberg of Lesotho stands out as a biogeographical treasure.'

Pteridophytes

Among the fern allies, isolated clumps of *Psilotum*, namely *P. nudum*, have been found growing in vertical rock crevices in the Roma valley. *P. nudum* from Lesotho was reported by Morgan (1962) and by Jacot Guillarmod (1971). The first reported site appears to be extinct, but a new site has been found on a cliff in a valley 2.5 km southwest of the original site (Hargreaves 1984 pers. comm.). Though lacking in aesthetic appeal, *Psilotum* is of very great scientific interest, being a representative of a group of land plants that appeared some 390 million years ago. *P. nudum* is not uncommon in the warmer, wetter areas of Africa. Lesotho specimens appear to have survived in a suitable microclimate in an otherwise relatively hostile environment.

Another fern ally descended from the Palaeozoic flora, is Isoetales. Its representative *Isoetes* has been reported from the rock pools in Sehlabathebe National Park (Zepp 1982). It must be mentioned here that at Sehlabathebe (2 400 m), the sandstone Clarens Formation outcrops at a much higher altitude than its usual maximum altitude of around 1 800 m. Zepp identified his specimen as *Isoetes natalensis*, now an accepted synonym of *I. welwitschii* (Jacobsen 1983) previously recorded in southern Africa from only two localities in Natal. Schelpe & Anthony (1986) mention Lesotho, together with Natal, Orange Free State and Transvaal, in connection with the distribution of *I. transvaalensis*. Again, as in the case of *Psilotum*, *Isoetes* is not a spectacular plant and it can be overlooked among aquatic grasses and sedges.

Ferns were not as abundant in the southern African coal measures as in those in the northern hemisphere. They were eclipsed by the Glossopterids (Plumstead 1969). However, they re-emerged in the Mesozoic era when many of the present families evolved. One of the simpler genera, *Ophioglossum*, is represented by two species: *O. vulgatum* and *O. polyphyllum* (Kali & Hargreaves 1985). The distribution of *Ophioglossum* is restricted to the vicinity of dolerite dykes where water tends to accumulate. This fern is becoming rarer with the increased sinking of boreholes near dykes to tap water resources.

Literally unique among the ferns, however, is the tree fern *Alsophila dregei*. Only one specimen occurs inside Lesotho's boundaries in Sehlabathebe National Park. *A. dregei* occurs in the adjacent Natal Drakensberg on stream banks and in gullies up to 2 300 m altitude (Hilliard & Burtt 1987). Is the Sehlabathebe tree fern a stray, or is it the last surviving specimen of a more extensive coverage?

Fossil evidence shows that nonflowering plants have managed to survive millions of years in suitable ecological niches. Their presence in modern times does not necessarily mean that they had a widespread presence in Lesotho since land plants first came into being, but merely that there were favourable, if very localized, conditions for their survival.

FLOWERING PLANTS

Flowering plants made their appearance in the Cretaceous period 110 to 65 million years ago. The fossil records of plant life (megaplants) are relatively meagre in southern Africa after the Triassic period and the picture of angiosperm evolution has consequently been constructed using evidence from now separated parts of the supercontinent Gondwanaland, of which Africa had formed a part up to the end of the Jurassic period. Thereafter Africa has remained isolated to develop a rich flora, particularly in the south, with a large number of endemic species (Plumstead 1969; Axelrod & Raven 1978).

Modern representatives of ancient genera

Euphorbiaceae are regarded as one of the oldest recorded angiosperm families in Africa (Plumstead 1969). Fossilized wood from this family has been recorded from the Cretaceous beds of Pondoland. *Euphorbia* is a very large genus with over 2 000 species (Dyer 1975) and widely distributed over Africa. Lesotho has 10 species of which *E. clavarioides* forms very striking cushion-like domes found on basalt slopes above 1 800 m. Its characteristic habit is an adaptation to the conditions in the mountains. At lower altitudes it grows only in dolerite dykes having basaltic soil or in places where basaltic soil has accumulated. 'The mountain populations are much bigger, both in plant size and number, than those of the dykes in the lowlands' (Hargreaves 1992). At lower altitudes the plant appears rather elongated and lax in comparison to the compact cushion found at higher altitudes (Hargreaves 1986 pers. comm.).

Proteaceae are also a family of great antiquity, and their distribution indicates that they originated before the break-up of the supercontinent, Gondwanaland. *Protea* shows a remarkable degree of diversification and development in southern Africa, particularly in the Cape.

The Cape floristic region is now much decreased in area from such times as when Africa lay 15° further south in latitude. Though decreased in extent, the Cape flora shows an astonishing degree of endemism for a land area (Goldblatt 1978), with many species of *Protea* endemic within the region: out of a total of 114 species occurring in Africa, 82 are in southern Africa (Rourke 1982).

Though restricted and confined mainly to the Cape, the proteas were more extensive in the past. Proteas are not common in Lesotho today, although it is likely that they were a common component of the Lesotho lowlands flora at periods

some 20 600 years before the present (Wadley *et al.* 1992). Species reported as currently found in Lesotho are *P. caffra*, *P. roupelliae*, *P. subvestita* and *P. dracomontana*. The distribution is disjunct in Lesotho and confined to the north and southeast of the country. Today *P. subvestita* and *P. dracomontana* are found just inside the Lesotho border at Sehlabathebe National Park. In the north, proteas are found in the Butha-Buthe district, with scattered specimens of *P. caffra* occurring on hillsides south of Ha Selomo, while further to the east the well-known Ha Mothuntšane woodland, first recorded by Arbousset in 1840 (Arbousset 1991), has some 4 000 trees of different ages. The local chieftainess controls how much dead wood may be removed by the villagers. Using a local name as a clue, *P. caffra* was also found in 1992, 1 km southeast of Ha Tšepe by the Likileng stream in the Leribe district (D.H. Maphisa, pers. comm.). The Sesotho name for *Protea* is *sekila* (in northern Lesotho) or *seqalaba* (in southeastern Lesotho). Following this lead, three localities called Liqalabeng on both sides of the Senqu (Orange River) were investigated in southeastern Lesotho. Proteas were found to have grown there in living memory, but have now become extinct. Phillips (1917) lists *P. caffra* collected by Mme Anna Dieterlen from Lefi's Nek, Leribe district, and comments: 'This protea is only found in one of the many ravines round the Leribe Plateau: it does not extend far into the ravine, but grows on the exposed grass slopes ... Unfortunately it is rapidly becoming exterminated, as the chief Jonathan now and then has trees cut for firewood; but this privilege Jonathan alone enjoys, otherwise the species would have long disappeared from the neighbourhood.' Proteas can no longer be found in the vicinity of the Leribe plateau.

The movement of the African plate to the north some 30 to 25 million years ago caused the interior to become drier, encouraging sclerophyllous vegetation. The genus *Erica* is thought to be a component of the once pervasive vegetation of those times (Schmitz 1984). Fourteen species are recorded from Lesotho of which two are common in the sandstone escarpments at lower altitudes. Most are found in the basalt-derived soils of the mountains. The Lesotho ericas have suffered a drastic reduction in numbers from being widely cut as fuel for domestic fires.

Common trees

The first written accounts of Lesotho's vegetation were by early travellers who described a landscape dominated by grassland. This impression has persisted over the years, although observations and the systematic mapping of tree species show the vegetation to be considerably more varied. Larger trees do survive in sheltered positions. Patches of woodland are found in ravines and in river valleys, but they seldom form a vegetation climax. The indigenous willow *Salix mucronata* can still be seen lining river banks, although in the western lowlands of Lesotho it has often been supplanted by the exotic *S. babylonica*, the weeping willow. Some subtropical woody species are today found only in the warmer river valleys of southern Lesotho. Examples are *Diospyros lycioides* subsp. *lycioides*, *Rhus dregeana*, *Aloe ferox*, *A. broomii*, and *Ochna* sp. *Aloe ferox* (Figure 1) is common

Figure 1.—*Aloe ferox* in the Senqu Valley, Quthing district.

on north-facing hillsides in the Senqu (Orange) River valley and occurs as far north as the lower parts of the valley of the Makhaleng, which is named after this aloe. *A. broomii* can be found along the Senqu as far north as the Malibamatšo (Semena) gorge east of the district headquarters town of Thaba-Tseka.

The most beautiful tree in Lesotho is *Dais cotinifolia* (*thotsoane*). It is very attractive in early summer when covered in heads of tubular pink flowers. Restricted to the Berea district, it is spreading into erosion gullies (dongas) and could possibly be used in donga stabilization programmes (May 1992). May reports his tallest measured tree as 9.1 m high and with a diameter at breast height (dbh) of 0.32 m. This specimen was growing near the village of Marabeng not far from the outskirts of Maseru.

Leucosidea sericea (*cheche*) is widespread in Lesotho despite its being a favourite fuel source (Hall & Green 1989). This preference has resulted in lowlands specimens often being isolated, small and mutilated, but in undisturbed areas of the foothills and the mountains they form dense stands. May's tallest measured tree is 15.5 m high with a dbh of 0.86 m, from Ha Lumisi in the Makhoarane plateau area (2 000 m), near Morija. Unfortunately this grand specimen was cut down in early 1993 together with another *cheche* in the same grove. However, both started to produce shoots from the stumps in the following spring. In addition to cutting

down *Leucosidea sericea* trees, the villagers also burnt down tall, dense stands of the bamboo *Thamnocalamus tessellatus*. The whole aspect of this woodland has now become more open (May, pers. comm.). It will be interesting to see what takes over!

The construction of the Hlotse Adit in the Phase IA area of the Lesotho Highlands Water Project at 2 100 m, has disturbed a pristine mature *Leucosidea* woodland with trees as high as 10 to 12 m. This area also contains a number of communities of the endemic bamboo *Thamnocalamus tessellatus* which apparently forms the habitat of the rare butterfly *Metisella syrinx*. The particular threat to this woodland is that the service road to the project site also provides access to the vehicles of wood collectors residing downstream from the construction camp site (Loxton, Venn & Associates 1993). It is important that this site is monitored frequently. Experience elsewhere in Lesotho suggests that as soon as a road is constructed, marketable plant products are under severe threat.

The wild olive *Olea europaea* subsp. *africana* (*mohloare*) is common in Lesotho. There are still sizeable communities forming open woodlands. The wood is much in demand, so it is hardly surprising that the trees have been greatly exploited in the densely populated lowlands. There are fairly extensive patches of olive wood, with old established trees in the upper Mokhokhong valley parallel to the Roma valley, but they are infested with *Viscum rotundifolium*, mistletoe, with attractive bright red fruits. In favourable localities, the wild olive develops into tall trees (up to 17 m as measured by May).

Myrica serrata (*maleleka*) is rarely found today, but occurs in the Maseru and Mafeteng districts on sandstone ledges on the escarpment (about 1 750 m) or lower down on stream banks. There are some isolated specimens near the University campus. It has also been found in Tele-Tele in Quthing district in the south and in the Butha-Buthe district in the north. There are records from the Leribe district (Phillips 1917). It is puzzling that this tree is not found in similar situations in the other lowlands districts. It seems likely that its numbers have been severely depleted in the densely settled lowlands because the roots are even today used as a remedy for headaches. The bark is also used as a charm against misfortunes (May 1992) and formerly at least (when it may have been more widespread) it was cut down for fuel (Phillips 1917). *Myrica* roots were recently (February 1994) seen for sale in the main street of Maseru.

Buddleja corrugata (*lelora*) is common in the foothills above 1 800 m and in favourable situations can be found at altitudes of up to 2 500 m or more, whereas the other common Lesotho buddleja, namely *B. salviifolia* (*lelothoane*), is found at lower altitudes. Woody plants are much in demand for fuel, and in springtime buddleja bushes can suffer from grass fires started by herders ahead of the rains to encourage new grass growth. Where undisturbed, they form dense patches. One such patch of *B. corrugata* in the upper Menyameng valley, Berea district, at an elevation of 2 420 m, had a tree 9 m tall with a dbh of 0.21 m.

Ilex mitis (*phukhu*) is an example of a nonpioneer climax forest tree (May 1992). Large trees are scattered far from one another. May surmises that dense forests of *I. mitis* have thinned out because other competing species have pushed the *Ilex mitis* seedings out from the stands. The tallest measured tree is 17.85 m tall, with a dbh of 0.80 m, found growing below the sandstone escarpment near Ha Lesoli, Maseru district. Similarly, *Scolopia mundii* (*qoqolosi*) could be considered a nonpioneering climax species.

One south-facing slope near the National University of Lesotho campus has been kept under particular observation (Talukdar 1981). Until recently when they finally wore out, *Scolopia mundii* roots provided footholds down the kloof giving access from the plateau above, resulting in the name *Khoro-ea-Mothapong* or 'Root Pass'. The woodland is on sandstone slopes between 1 630 and 1 780 m, and this small patch has 27 indigenous tree species. What has protected it to some extent is, firstly, that the sides are too steep and difficult for local wood gatherers, and secondly, the vigorous growth of the exotic wattle *Acacia dealbata* has provided local people with a viable alternative source of firewood.

Tree plantations have been encouraged in Lesotho by the colonial authorities and by missionaries since the middle of the last century. Photographs show mature trees established in several of the main administrative centres and villages of Lesotho by 1880. The planted trees were mostly exotic species, poplars, pines, wattles and gums. The first three have spread extensively, displacing the indigenous vegetation. The gums, species of *Eucalyptus*, readily regenerate after the tree has been cut. During the past 20 years, small forestry reserves, commonly called woodlots, have been established, and if properly managed, can take the pressure off the indigenous species which grow and regenerate very slowly.

GRASSLANDS, HERBS AND SHRUBS

Original grassland climax and changes

Lesotho is regarded by Rutherford & Westfall (1986) mainly as part of the Grassland Biome which occupies 83.26% of its land area. The remaining 16.47% falls under what they call the Nama-Karoo Biome, corresponding to areas above 2 800 m, with mires, alpine grassland and heath. There are many local variations within the two biomes, depending on small differences in physical, edaphic and biotic influences, of which most notably in recent times are human activities.

Most of the Lowlands Zone of Lesotho between about 1 350 and 1 800 m altitude was formerly covered with *Themeda triandra* (*seboku*) and other associated grasses such as *Hyparrhenia hirta* (*mohlomo*) on the warmer slopes and *Cymbopogon plurinodis* (*patiane*). It is thought that the grassland vegetation developed as a result of interruptions in its progression to the seral succession beyond this stage by fires and grazing which would destroy the seedlings of larger woody species. That trees can grow even on the summit plateau, is illustrated by

a plantation started in the extreme climate of Letšeng-la-Terai at 3 000 m altitude, where planted pine seedlings grew to over 3 m in 14 years on an exposed slope within a fenced area, without any attention. *Leucosidea sericea* seedlings planted in 1990 in the same enclosure grew after dying back to ground level in the winters of 1990 and 1991 (May, pers. comm.).

The *seboku* pastures, according to Staples & Hudson (1938), are the most valuable pastures. This was undoubtedly realized by the early pastoralists in Lesotho. However, political upheavals in the previous century and in the early years of this century forced many more people and their livestock into a much shrunken area, so that pressure on the *seboku* grassland has increased while most of the original *Themeda* grassland has been converted into fields and homestead plots. The present increased rate of urbanization has meant that there is a migration of people from the mountainous region to the urban centres in the lowlands. For example, the population of greater Maseru grew by 6.9% between 1976 and 1986 (Ambrose 1993), whereas the overall intercensal growth rate during those ten years for Lesotho was 2.8% (Lesotho Government Bureau of Statistics 1992). As a result more land near the urban settlements is being given over to buildings, industries and roads, decreasing the extent of fields and pastures.

Opinions differ as to the extent of overstocking in Lesotho but estimates suggest that there are currently 2.5 to 4 times the number of animals the grassland vegetation of Lesotho is capable of sustaining in good health (Lesotho Government Ministry of Planning 1987). Adverse effects of overgrazing, namely degradation of pasture, loss of topsoil through the removal of vegetation cover and soil erosion, have been extensively documented (Staples & Hudson 1938; Jacot Guillarmod 1968, 1971; Schmitz 1984; Lesotho Government 1989).

Grasses, given time and a period of rest from grazing, can regenerate from a basal meristem. However, heavy use of the natural pastures has led to the replacement of the palatable grasses by coarser tufted grasses which are better able to withstand pressure from grazing animals. Grasses such as *Eragrostis* spp., *Aristida congesta*, *Trichoneura grandiglumis*, and tough shrubs such as *Felicia filifolia*, *F. muricata* and *Stoebe vulgaris* invade the overgrazed grasslands.

Cultivation has introduced many exotic weeds, common among which are *Argemone subfusiformis* (Mexican poppy, *hlabahlabane*), *Tagetes minuta* (khakiweed, *jeremane*) and *Datura stramonium* (thorn apple, *letjoi*), all immigrants from the New World. Poplars and Kikuyu grass, *Pennisetum clandestinum*, have been planted to stabilize erosion gullies. Peach trees and the sweet briar, *Rosa rubigenosa*, are now part of the flora in the fields, though initially exotic.

Human activities and settlements thus cause profound disturbances of the indigenous flora. There were open spaces around the University of Roma at the time of Independence in 1966. Marthe Schmitz, lecturer in botany, found eight species of orchids on a hillside to the southwest of the campus in 1958. The open

lands around the campus subsequently became areas of informal local housing and Mrs Schmitz recorded only a single species surviving in the area in 1980.

The Foothills Zone of Lesotho is separated from the Lowlands Zone to its west by the sandstone-basalt interface which is generally at 1 800 m altitude, although in the south the altitude of the interface varies from 1 550 m to 2 320 m. The Foothills Zone is in turn separated from the Mountain Zone to its east by the Front Range of the Maloti (commonly and erroneously called 'Maluti Mountains' in South Africa: *Maloti* means 'mountains' in Sesotho). The foothills are characterized by narrow river valleys (except for the major rivers) and high ridges in between. The sides of the valleys are sometimes covered with dense growths of trees such as *Buddleja salviifolia* (*lelothoane*) or *Leucosidea sericea* (*cheche*). The bamboo *Thamnocalamus tessellatus* (*leqala*) forms conspicuous thickets. Staples & Hudson (1938) found *seboku* grassland on the warmer slopes from 2 000 to 2 700 m above sea level, encompassing Killick's (1978a) subalpine belt where *Themeda triandra* can form pure stands in protected places. It was collected even at an altitude of 2 900 m at Sani Top (Killick 1989). *Eragrostis curvula*, *Cymbopogon excavatus* and *Hyparrhenia hirta* also occur in the *seboku* pastures on the lower foothills.

Population pressure and the increasing dearth of cultivable land in the lowlands have resulted in intensive cultivation of the foothills, and the fields are sometimes on steep slopes not very suitable for agriculture. The upper limit of cultivation can reach as high as 2 440 m (Jacot Guillarmod 1971).

Livestock management in Lesotho involves the movement of the animals to the mountain valleys for the summer and to the lowlands during the winter. This pattern is changing from the previous transhumance system. Livestock owners are depending more and more on intermediate 'winter' grazing posts in between the two, accessible within two or three hours' walk from the villages. During bad weather, the animals can then be moved back quickly to the villages, and up to the mountain pastures when there is inadequate grazing around the villages. Hence the lower foothills pastures are being grazed more intensively (Quinlan 1993). One of the most noticeable effects is the rapid spread of *Chrysocoma ciliata* (*sehalahala*) (Figure 2) and *Pentzia cooperi* (*leriane*) in the grassland communities.

At higher elevations above 2 750 m, *Festuca caprina* (*letsiri*) becomes dominant on the northern slopes. On the cooler southern slopes, *letsiri* is more dominant than *Themeda triandra* above 2 135 m (Killick 1978b). Patches of *Merxmuellera macowanii* (*moseha*) are seen along stream banks and *M. drakensbergensis* (*moseha*) along the lines of water seepage. The presence of the grasses *Karoochloa purpurea, Catalepis gracilis* and *Harpochloa falx* indicates trampling and disturbance by animals. The unpalatable *Helichrysum trilineatum*, the hard wiry-leaved shrubs *Chrysocoma ciliata*, *Felicia* spp., *Gymnopentzia bifurcata*, *Metalasia densa*, all with the Sesotho name *sehalahala*, are able to survive in grazed areas.

Figure 2.—Grazed slope south of Blue Mountain Pass, Maseru district, at 2 700 m, with *Chrysocoma ciliata* bushes. The white-flowered *Helichrysum sutherlandii* is growing beside a shielding rock.

Hydrophytes

In the dams and marshes within the Lowland Zone, stands of the reed *Phragmites australis* (*lehlaka*) and tall grasses such as *Imperata cylindrica* and *Miscanthus capensis* are conspicuous. In the water itself, the aquatics *Crassula natans*, *Marsilea macrocarpa*, *Potamogeton thunbergii* and various sedges and floating algal masses are indigenous. Some dams and reservoirs are now covered with invading duckweed (*Lemna* sp.) which may impart an unpleasant taste to the water. However, a particularly dangerous water weed has recently invaded one of the dams on the University campus at Roma. This is the notorious parrot's feather (*Myriophyllum aquaticum*), originally from South America. It was noticed in January 1993 when there was a drought and the level of the dam was low. The growth was then already so luxuriant that an adult was able to walk on the floating carpet with ease! A certain amount of clearing by hand was attempted by biology students, and the lifted weed was dried and burnt. Much more remains to be done to clear the dam, and a successful eradication technique remains elusive. So far this is the only known case of *M. aquaticum* infestation in Lesotho, but with the dam overflowing during heavy rain in January 1994, a spread to downstream dams is possible.

Concern has been expressed about the deterioration of the alpine mires in the mountains of Lesotho (Jacot Guillarmod 1962, 1963, 1969; Backéus 1988; Meakins & Duckett 1993). The main threat is posed by animals grazing around them and trampling the sides, causing erosion. In addition, small animals browse even on the bog vegetation, especially on species of *Rhodohypoxis* (Jacot Guillarmod 1969). Jacot Guillarmod (1969) also points out the damage done to the mires by diamond prospecting in the mountains. Diamonds are associated with kimberlite pipes where springs are often located. Excavating the kimberlite destroys the ecosystem. Although the springs may flow again, the mires are no longer able to filter the water and to act as sponges for maintaining a constant supply of water of good quality. High-altitude mires are the sources of the Senqu (Orange) and its tributaries which supply Lesotho, South Africa and Namibia with water. The access road to the first large dam construction site of the Lesotho Highlands Water Project goes across an alpine wetland in the headwaters of the Bokong, ultimately part of the Orange River catchment. Construction work has caused serious changes in the wetland (Meakins & Duckett 1993; Schwabe 1993). The road builders have constructed culverts beneath the road, draining part of the wetland. The Bokong wetland, in common with other similar mires, has also been affected by grazing which has reduced the grass cover on the slopes, increasing the intensity of the runoff and consequent erosion. The drying out of parts of this delicate hydrological system is a matter that has attracted concern, and attempts at rectification have been made at the road crossing by using gabions upstream. These, however, have had a tendency to overcompensate by flooding the area above the road with too much water.

Many of the aquatics are unique at high altitudes. The Sehlabathebe lily (*Aponogeton ranunculiflorus*) grows in the rock pools of the Sehlabathebe National Park at 2 400 m and also 2 km away across the border from Sehlabathebe (Jacot Guillarmod 1978). It has also been reported from the Thaba-Putsoa Range (Schmitz 1982).

Endemism and speciation

The mountains of Lesotho together with the Natal Drakensberg, the Cape Drakensberg, the Witteberge, and the mountains of the northwestern corner of the Orange Free State constitute the Drakensberg centre of endemism (Schmitz 1982). It is estimated that as many as 30% of the species may be endemic. The Drakensberg centre is thought to be a centre of speciation as well, where new species may arise through hybridization and isolation.

Endemism is particularly prevalent at high altitudes. *Helichrysum palustre*, for example, has been recorded only from the high mountains of Lesotho and the summit plateau of the Drakensberg between 2 300 and 3 400 m (Hilliard 1983). It grows in marshes or along marshy stream beds. *H. qathlambanum* has been found only in the Butha-Buthe district and in the Natal Drakensberg between 1 800 and 3 000 m (ibid.). *Kniphofia hirsuta*, the hairy red-hot poker, has been found at

Mamalapi in the Berea district (Codd 1968) and along the Mountain Road in Lesotho (Schmitz 1982). *K. northiae* is a Drakensberg endemic. *Saniella verna* from the Sani Pass area was found to belong to a new genus within the Drakensberg centre (Hilliard & Burtt 1978). In Lesotho it was found near Blue Mountain Pass by Schmitz and at Ribaneng by Zepp. *Saniella*, *Rhodohypoxis*, *Gladiolus saundersii*, and the orchids *Brownleea* (4 species in Lesotho), *Disa fragrans* and *Disperis wealei* are all regarded as Drakensberg endemics. Whether they are neo-endemics or palaeo-endemics is often difficult to decide, but either way they are notable items worthy of conservation. Among the dicotyledons, mention may be made of *Glumicalyx lesuticus*, *Dianthus basuticus* var. *basuticus* endemic to Lesotho, and *Glumicalyx nutans*, *Craterocapsa montana*, endemic to the Drakensberg centre. A new species of *Crassula*, *C. qoatlhambensis*, has been found at Tlaeeng Pass and Kotisephola Pass in the Mokhotlong district and in two localities near Sani Pass, Thaba-Tseka district, all around 3 000 m altitude (Hargreaves 1989).

Special mention must be made of the most spectacular endemic plant of Lesotho, the spiral aloe—*Aloe polyphylla* (Figure 3). Much has been written, said and reported about this unique aloe which grows naturally only on the basaltic slopes of Lesotho above 2 000 m altitude. Perhaps the publicity surrounding *A. polyphylla* came to be its own worst enemy, since it acquired something of a status value. Both local people and visitors now want it for their own gardens. The aloe, however, seldom survives as a garden plant for more than five years because it has specialized soil and moisture requirements. Its protected status is well known in Lesotho and has been widely broadcast, which only seems to make it more desirable!

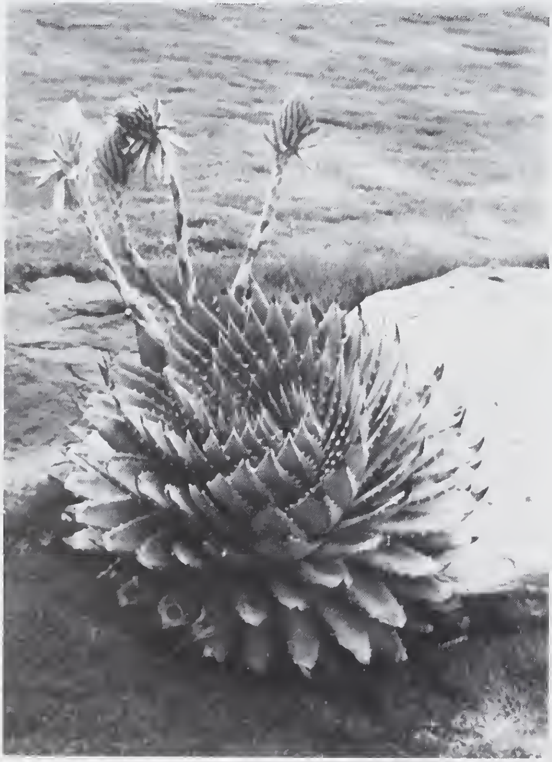

Figure 3.—*Aloe polyphylla*, the spiral aloe.

The uprooting and sale of spiral aloes continues unabated, despite its protected status. For example, on 18

May 1993 a small spiral aloe was purchased for M2 at the University gate at Roma by a student who was doing an aloe census. The aloe seller had about ten young plants, taken from the Jorotane catchment in the Phase IB area of the Lesotho Highlands Water Project. His taxi fare to Roma must have cost him at least M10; so he made only M10 for all that trouble and ten young plants were lost from their site. On 10 June 1993, ten small aloes were observed in a garden in a Maseru suburb, and on the 19th, two were spotted in another garden in the peri-urban area of Maseru. The price was higher: M10 each. On 26 June I was told of two spiral aloes in a garden in the industrial border town of Maputsoe. Plants were also being sold in a shop in Butha-Buthe. All these localities are totally unsuitable for the spiral aloe. Young plants were seen as recently as 24 February 1994 for sale at a herbalist's open air counter in the main street of Maseru.

Since 1976, a census for spiral aloes has been maintained for a site within close reach of the Mountain Road near Likalaneng (Talukdar 1983). It is a slope facing northwest, rising from 2 440 m to a summit at 2 650 m. There were 373 plants in 1986. In 1988 the counting could not be finished because of a thunderstorm, but the aloes were still flourishing on the hillside. A census undertaken in 1993 as part of a student project by P. Mabea of the Biology Department was a shock: there were only 18 aloes left at the site, and most of these were damaged. There was also considerable evidence of recent removals.

LESOTHO HIGHLANDS WATER PROJECT

The Lesotho Highlands Water Project (LHWP) has already been mentioned as a major human intervention impacting on Lesotho's environment. Some mention of its magnitude and scope is therefore relevant to any account of Lesotho's flora. The entire project (Figure 4) is planned as a four-phase construction of five major dams, four transfer tunnels, two delivery tunnels and two pumping stations (Lesotho Highlands Development Authority c. 1988).

The Project's main aim is to provide additional industrial water supplies for the Pretoria-Witwatersrand-Vereeniging (PWV) complex. If all planned phases of the Project are completed, ultimately (perhaps in 35 years' time) 70 m^3 s^{-1} of water will be diverted from the headwaters of the Senqu (Orange) in Lesotho to the Vaal catchment in South Africa. Lesotho will receive royalties on all diverted water leaving the country and the 'Muela Hydropower Station will generate 72 MW of electricity to be fed into Lesotho's power grid.

It is estimated that when all the phases are completed, LHWP will have a cumulative catchment area of 11 345 km^2, more than one third of Lesotho's total area.

Implementation of Phase IA of the LHWP is now well under way. The roadbuilding activities to serve the construction teams began in 1987. Experts looking into the effect of the project on the flora were of the opinion that LHWP does not directly threaten the status of any of these plant types: *Aloe polyphylla*,

Figure 4.—The scope and extent of the Lesotho Highlands Water Project. The proposed sequence of construction from Phases I to IV and their probable time scales are shown in boxes.

Delosperma ashtonii, *Kniphofia thodei* and species of *Rhodohypoxis* (Loxton, Venn & Associates 1993). This optimism is not borne out by experience in the field, as the poster presentation on the spiral aloe by Mrs M. Mothepu from LHWP so vividly illustrated at the International Conference on the Conservation and Utilization of Southern African Diversity in September 1993: increased accessibility results in removal of plants known to have sales value, even when they are not directly affected by construction work.

Phase IB of the Lesotho Highlands Water Project will see the construction of Mohale Dam, scheduled to be completed in 2002. The infrastructure for this phase is already at the design stage. The depleted spiral aloe site mentioned previously near Likalaneng, is in the Mohale Dam catchment. The construction of roads bringing people and large vehicles to hitherto remote areas, will have effects which will be felt far beyond the construction sites and road camps. There is therefore a severe threat to the small number of remaining spiral aloe sites in the valley of the Senqunyane River, the waters of which will be impounded by the Mohale Dam.

CONSERVATION

Lesotho is a country with a surprising degree of botanical diversity. Some groups like algae and fungi have not received much attention, but are important in hydrology and pedology. The first essential requirement for conservation is a complete inventory of plants which can be revised and updated regularly, a strategy also emphasized in the Conference on Conservation of Biodiversity in Africa (Crowe & Siegfried 1993). A very useful checklist is given in *Flora of Lesotho* by Jacot Guillarmod (1971). A species list for southern Africa was brought out by Gibbs Russell *et al.* of the then Botanical Research Institute (BRI), Pretoria, in 1984. In the following year, the PRECIS checklist for Lesotho from BRI, Pretoria, listed 1 961 species from bryophytes to angiosperms. Jacot Guillarmod's (1971) corresponding number is 1 651. As the flora in the hitherto unexplored areas of Lesotho is surveyed, the number will change. It is also important to investigate areas that have been botanically investigated in the past to find out how the flora is changing with time. The National University of Lesotho Herbarium (ROML) has a plan to set up its own database. In addition, the Documentation Centre of the Institute of Education of the National University is maintaining a database on environmental matters as the Lesotho INFOTERRA National Focal Point.

Plants that have a commercial value cannot be protected by legislation alone. The law-enforcing arm must be strengthened and the personnel made conversant with what is protected and why. It is not practicable to expect that the remedy lies with the police alone. Involvement of the local population in controlling access to the protected plants is much more realistic. Mention has been made of the protected *Protea* woodland which is under the control of the local chieftainess. People are not totally denied the use of its product as long as they take the dead wood. It is an example of conservation where the involvement of the local community has a tangible benefit.

Such experience suggests that the villagers close to spiral aloe sites should be encouraged to become their caretakers. They could set up aloe nurseries from seeds and sell the young plants with a sale certificate. Villages could keep the proceeds and in that way they would have a direct interest in keeping the sites viable and the nursery going.

The cooperation of villagers in conservation has been successfully tried elsewhere, notably in Zimbabwe. Under the CAMPFIRE (Communal Areas Management Programme for Indigenous Resources) project, rural communities are managing to make money from animals that were formerly poached as pests. The programme is simultaneously encouraging economic development and a conservation awareness in rural areas of Zimbabwe (Holt-Biddle 1994). The essence of collaboration is that rural people are paid promptly to keep up the momentum of sustainable development in their own villages.

The problem of the decline of rangeland and the extension of cultivation and permanent settlement in the mountains will have to be addressed at the local level. Many policies have emanated from donor agencies and from the central government, but they have failed because these ideas came from outside the community. Grazing associations, for example, have not been very successful so far, and a scheme by which Village Development Councils were empowered to charge grazing fees was abandoned in 1993 after little more than one year of operation. The new Lesotho Government, which assumed office in 1993, is now looking at ways to strengthen local government and to replace former 'top-down' planning with community-based rural development in which local people are more directly involved in planning their own environment.

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Botanical diversity in Namibia—an overview

G.L. MAGGS*, H.H. KOLBERG* and C.J.H. HINES**

* National Botanical Research Institute, Private Bag 13184, Windhoek, Namibia.
** P.O. Box 22527, Windhoek, Namibia.

ABSTRACT

Botanical research in Namibia has been sporadic through the century preceding Independence. There have been no attempts at characterizing the diversity of the flora, and consequently centres of endemism, species richness and conservation concern have not been clearly identified. Distributional data on about 150 endemic or near-endemic species are used here to identify areas of particular botanical importance (see Appendix). Botanical research is strongly supported by the Government of Namibia and development aid agencies, but is hampered by a lack of trained staff, funding and problems accessing botanical data from former colonial administrations.

INTRODUCTION

Namibia is situated on the southwestern coastline of southern Africa, covering a total surface area of 823 145 km^2. The topography of the country is extremely varied—from sand-dunes to grassy plains to granite inselbergs and high mountains—but is dominated by an escarpment along the western side of the country which forms a transition between the coastal desert and the savannas of the interior. The highest mountain masses occur in the northwest (Kaokoland) and around Windhoek in the central territory (Giess & Tinley 1968). The northeast and eastern parts of the country form the western sector of the Kalahari Basin.

Namibia is the most arid country south of the Sahara with rainfall being the key factor that drives all important ecological processes. The most important climatic parameter is rainfall variability which is inversely proportional to the mean annual rainfall. Rainfall increases from the southwest to the northeast of the country, varying from an annual average of less than 200 mm in the Namib Desert to 700 mm in the northeastern Caprivi Strip. Mean annual rainfall for Namibia as a whole is 270 mm, with 22% of the country receiving under 100 mm, 33% receiving 100–300 mm, 37% receiving 300–500 mm and the remaining 8% receiving 500 mm or more (Van der Merwe 1983). Summer rains occur in the form of convectional thunderstorms over the major portion of Namibia, but episodic winter rainfall occurs in the southwestern Namib.

HISTORICAL PERSPECTIVE

Since the discovery of *Welwitschia mirabilis*, international botanists have regarded Namibia as a hunting ground for unusual and often unique plant species. However, botanical research has been sporadic throughout the century preceding Independence.

Following extensive collecting missions undertaken by the University of Munich in the 1960s and '70s, the floristic reference *Prodromus einer Flora von Südwestafrika* (Merxmüller 1966–1972) was published. Although Namibia is also included in the *Flora of southern Africa* (*FSA*) and partially in the *Flora Zambesiaca* projects, the *Prodromus* provides the only diagnostic keys and descriptions for all the Namibian plant taxa. An update on the inventory of taxa occurring in Namibia was undertaken by the staff of the National Herbarium and published recently (Kolberg *et al.* 1992).

From species distributions approximated during intense collecting activity for the *Prodromus*, a vegetation map for Namibia was produced in 1971 (Giess 1971) which divides the vegetation into three broad categories, namely deserts, savannas and woodlands. These were then further subdivided into 15 types based on characteristic physiognomic structure. However, as our vegetation resources form the basis of almost all land-use practices in Namibia, an urgent need exists to update this approximation of vegetation units.

There have been no attempts to assess or analyse the flora or to characterize diversity and consequently centres of endemism, and species richness, geographical affinities and conservation status have not been clearly identified.

In this paper, an attempt has been made to assess the relative species richness based on partial surveys and distribution data from the outdated *Prodromus*.

SPECIES DIVERSITY

An approximation of species diversity was attempted using the *Prodromus* as well as other relevant literature, e.g. *FSA*, checklists and personal communication with local botanists.

As this is the first approximation ever, the results will be tentative and subjective, liable to re-examination when the gradual accumulation of evidence permits.

The distribution of 3 540 plant species per magisterial district as indicated in *Prodromus* was plotted, with results indicated in Figure 1.

Southern Namib: 33.8%

Previous investigations (Robinson 1975) were confirmed in this analysis, in that the southern Namib area is host to 33.8% of the total number of plant species

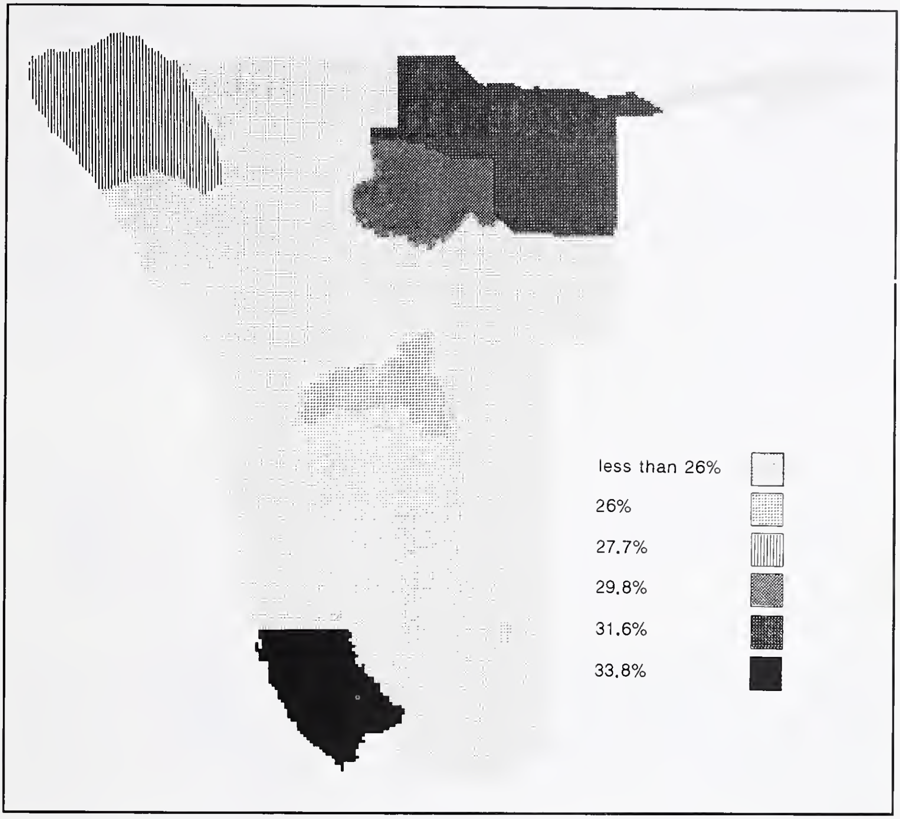

Figure 1.—Centres of diversity.

occurring in Namibia. As the area under review is composed of both winter and summer rainfall areas plus a transitional zone, one would expect to encounter this high diversity. Speciation of succulent groups like the mesems appears to be occurring and will have contributed to the high species number. Two factors may have artificially inflated the diversity. Firstly, the taxonomy of many groups is a problem and may have led to inadequate delimitation of taxa and secondly, high collecting intensity cannot be overlooked as a reason for high species numbers.

Grootfontein: 31.6%

This area includes the Otavi Mountainlands/Karstveld which probably contributes considerably to the overall high species diversity in the area. This mountainous area provides habitats of higher altitudes in the Kalahari Basin and supports relic populations of southern elements with an earlier widespread

distribution, e.g. *Hereroa*. This district consists of a number of habitat types, e.g. windblown sands in the east, shallow sands on calcrete as well as calcrete outcrops. In addition, it is one of the highest rainfall areas in Namibia.

Kavango: 29.8%

The high incidence of species in this district is probably due largely to the incursion of tropical species down the Okavango River. Also encountered are elements of the Zambesian Domain which is characterized by a large number of species, albeit of wide distribution. The diversity of habitats within the boundaries of this district contributes significantly to the species richness. Habitats found here include:

- wetlands
- dry woodlands on sand
- microphyllous woodlands on clay
- riverine forest
- specialized habitats on the quartzites of the Andara region.

A high rainfall is also experienced in this district.

Kaokoveld: 27.7%

This region is acknowledged as having high floristic individuality but also showing a very strong relationship with the Sudano-Zambezian region. The flora is composed of a high number of endemic elements as well as linking elements to the rest of the Karoo-Namib and also across the Kunene to Angola. A number of species belong to a group of taxa with disjunct distribution between the arid regions on either side of the equator which indicates a former connection between southwest and northeast Africa, e.g. *Kissenia, Sesamothamnus.* A variety of habitat types are also encountered in this district and it has long been believed that the basic geological formations exert a considerable influence on the vegetation of this area.

Windhoek: 26%

The high species diversity in this district is almost certainly an artifact caused by high collecting intensity. However, the possibility of increased species richness due to the presence of high-altitude habitats, e.g. in the Auas Mountains, needs to be investigated.

ENDEMISM

In order to get a clearer indication of endemic distribution in Namibia, 145 endemic or near-endemic plant species were randomly chosen, and their distribution was plotted per half-degree square. An overall figure for number of endemics

per surface area in Namibia would be very misleading due to the high concentration of endemics in certain areas.

The endemic flora and fauna of Namibia are confined chiefly to the Namib Desert and the adjoining mountainous country of Kaokoland. A few endemics extend out of this region onto the interior Continental Plateau on which there are ranges of rocky mountains (Tinley 1971).

The following were highlighted as areas of endemism (Figure 2):

Kaokoveld

In addition to the high species diversity already discussed, this is an important area of high endemism. Previous studies seem to indicate that these endemics

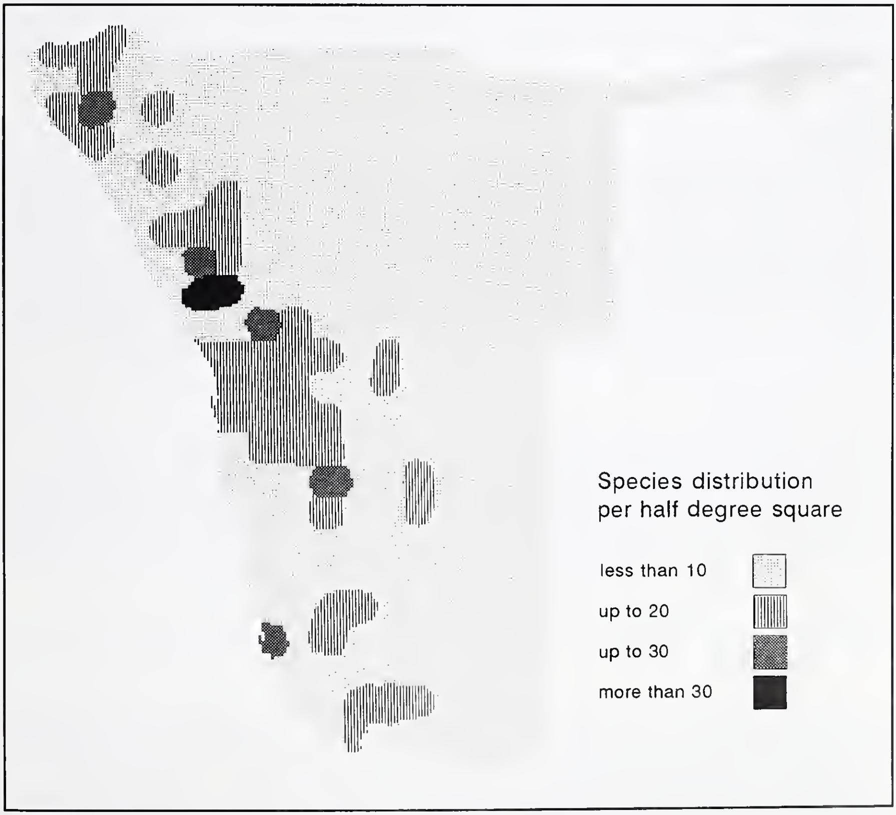

Figure 2.—Centres of endemism.

are well defined species with few close allies. Many give the impression of being very old which is enhanced by the presence of taxonomically isolated, monotypic genera like *Welwitschia* and *Kaokochloa*. Many are endemic relics with connections to northeast Africa, while intense recent speciation is occurring within certain groups, e.g. *Petalidium* (Nordenstam 1974). An area particularly rich in endemics is the Brandberg, which falls within the southernmost extension of Kaokoveld. The high altitude of this isolated relic inselberg and the cool, moist conditions at its summit, could be a possible explanation for the relatively high incidence of endemism. Although the flora of the Brandberg appears to be somewhat unique, further studies on the surrounding inselbergs need to be undertaken to confirm this as the distribution of certain species, e.g. *Nicotiana africana*, indicates that the endemics may be more widespread than previously thought.

Windhoek

The high occurrence of endemism here is almost definitely an artifact of high collecting intensity. However, the Khomas Hochland complex contains endemics from other biotic groups, e.g. butterflies, lizards and beetles, and may possibly also be an area of high floral diversity.

Naukluft

It is unclear why there is a high occurrence of endemism in this area although it is possibly an artifact of high collecting intensity within a nature conservation area. However, its position along the western escarpment together with the presence of numerous springs and water holes, could be offered as a possible explanation. The substrate of dolomites and limestones, which differs geologically from the surrounds, could also be an important factor contributing to its unique flora (A. Günster pers. comm.). This area warrants further investigation.

Southern Namib

The high level of endemism in this area concurs with preliminary investigations conducted in the area. Recent speciation within the succulent groups could be contributing to the high incidence of endemism. The very high number of plant endemics for the Lüderitz Peninsula is in concurrence with endemic distribution data for other biotic groups like lizards (M. Griffin pers. comm.)

CONSERVATION STATUS

The Constitution of the Republic of Namibia makes provision for the conservation of biodiversity as part of government policy: ‘The State shall actively promote and maintain the welfare of the people by adopting ... policies aimed at ... the maintenance of ecosystems, essential ecological processes and biological diversity in Namibia and utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future ...’ (Article 95).

About 13% of Namibia is proclaimed conservation area. This existing protected area network does not protect the full range of vegetation types. For example, mixed savanna, camelthorn savanna and mountain savanna have no formal conservation status.

However, these savanna veld types compose most of the commercial farming area. About 40% of commercial farmland is game farm-orientated and most farmers are sensitive to conservation requirements which implies that although not formally conserved, these vegetation types are receiving some measure of protection.

There is some cause for concern when comparing the distribution of endemic species (along the western escarpment) with proclaimed nature conservation areas—a major portion of these centres of endemism falls within the communal farming areas of Damaraland and Kaokoland. An obvious approach for determining conservation areas is to select areas containing high numbers of endemics. The effective conservation of the flora requires the up-to-date knowledge by conservation authorities of the precise location of especially threatened and endemic flora.

Although the southern Namib is protected within the Diamond Area 1 of CDM (Consolidated Diamond Mines), this is only a temporary concession. The mining activities themselves cause some disturbance to the natural environment, while the recreational activities of local inhabitants, e.g. 4 × 4 off-road driving and lucrative plant poaching activities, pose a more serious threat.

No adequate methods of law enforcement are in place to protect individual species. The list of protected plants under the Nature Conservation Ordinance of 1975 is desperately in need of revision.

THREATS TO CONSERVATION

Although the nature and extent of threats are not well documented, there are indications that the level of protection will need to be improved. In the past, conservation areas were not selected systematically and decisions were subject to short-term political considerations. A major problem experienced in Namibia at present is the unco-ordinated approach to land-use planning.

Namibia is very fortunate in that the human population is very low, and the high rates of extinction and severe environmental degradation experienced in some countries have not yet occurred.

RESEARCH PRIORITIES

From the information available, certain research priorities have been identified. There exists a fundamental need to expand plant collecting within Namibia in order to get a clearer picture of the distribution of taxa. Gaps in collecting and

inadequate distribution data need to be rectified. An update of the Namibian flora will be imperative for future management purposes as conservation needs to be implemented on a basis of better evidence than has up to now been available.

By overlaying the information obtained for this paper presentation, it is clear that the following areas warrant further attention:

Kavango River system

This is an area of high species diversity which has an extremely high human population (25% of the Namibian population). As the vegetation resources are important in the subsistence economy of the Kavango, great demands are placed on this resource. The availability of water from the Okavango River has resulted in large tracts of land being cleared for monoculture cash-cropping as well as for fields for subsistence farming of traditional crops. These factors, coupled to high livestock densities, have resulted in the disappearance of an estimated 70% of the riparian woodland/forest, degradation of seasonally flooded grazing areas and increasing siltation of watercourses. Certain sites of special interest (e.g. Andara) warrant immediate attention.

Kaokoveld

Being a highly inaccessible area, the Kaokoveld is relatively undercollected and the flora of especially the mountain ranges is largely unknown. Recent fieldwork in the area has produced a preliminary checklist which indicates a number of previously unrecorded taxa (Craven & Maggs 1993).

Large-scale development along the Kunene River, e.g. construction of a hydroelectric scheme at Epupa Falls, will seriously threaten the survival of a number of endemic plants, fish and other vertebrates both at the site of construction which will be subjected to flooding and downstream where the water level will be drastically affected.

Southern Namib

The fact that the flora of this region shows very distinctive adaptive characteristics and that it is the area with the highest concentration of plant species in Namibia, should be sufficient to warrant it a priority for further investigation. Most studies conducted to date have been species-specific and mostly of a taxonomic nature only. A basic lack of information regarding the vegetation of the transition zone between the winter and summer rainfall areas has been identified as a shortcoming (Jürgens 1991).

A synecological survey of this area is presently being undertaken by the Ministry of Wildlife in an attempt to identify plant species and localities deserving high conservation priority.

Plant poaching of 'spectacular succulents' is known to occur in the area but no data exist as to the exact quantities removed and the impact on the populations.

Western escarpment and inselberg systems

The western escarpment generally forms the cutoff line for endemics, not only in plants but for all biotic groups in Namibia.

As previous studies have indicated that speciation is occurring on the Brandberg, botanical studies on the surrounding inselbergs could provide useful evidence to examine the island biogeography theory.

PROBLEMS

As is the situation within other SADC countries, lack of adequately trained manpower is one of the most serious problems limiting botanical research in Namibia. For example, of the 133 students registered as first-year B.Sc. students at the University of Namibia (UNAM) since 1986, only 27 have graduated, with 13 of these having Botany as a major subject (D. Vermeulen pers. comm.). No postgraduate facilities exist at UNAM at present. Although various scholarship programmes are available for postgraduate training within Africa and abroad, the lack of graduates renders Namibia unable to make full use of this opportunity.

Budgetary shortages within Government have severely limited funding for research. Donor agencies have appeared willing to consider the financing of applied studies but funds for theoretical/academic research remain elusive.

Current research work is hampered by the unavailability of baseline data from previous colonial administrations. In an attempt to secure all data generated from research conducted by foreign scientists within Namibia, the Permit Office of the Ministry of Wildlife Conservation and Tourism has implemented stricter controls.

WHERE TO NOW?

Since Independence, the National Herbarium has been expanded to encompass various associated disciplines such as a gene bank and tissue culture unit in addition to the traditional tasks of identification and taxonomic research. An urgent need has been identified to develop a programme under the auspices of the National Botanical Research Institute, as the facility is now known, which will link research to the economic importance of our botanical resources both in the commercial sector and in subsistence economies.

This programme will have a multidisciplinary approach including aspects of ethnobotany, taxonomy, ecology, plant genetic resources conservation and biotechnology.

The initial step in setting up this programme will be to computerize the holdings at the National Herbarium. An easily accessible inventory of plant resources and their distribution will be critical in finalizing priorities and will facilitate effective research.

CONCLUSION

Although it is apparent from this preliminary analysis that a great amount of work still needs to be done, it is also clear that with the limited knowledge available, certain trends can be identified. It is not essential for all information to become available before conservation strategies can be formulated.

Although Namibia does not have a high diversity in terms of species number, the flora should not be discounted in terms of value. The harsh environmental conditions in Namibia are unique and have led to the specialization of many plant species. These taxa have great potential for use elsewhere in arid countries or in areas undergoing desertification due to agricultural malpractices.

As the Namibian Government is committed to the maintenance of biological diversity, locally, regionally and on a global scale, and recognizes that the greatest threat to biodiversity is the nonsustainable utilization of natural resources and uncontrolled development, it welcomes the initiatives taken at this meeting to resolve problems and develop conservation strategies for the benefit of the entire southern African region.

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APPENDIX

ENDEMIC OR NEAR-ENDEMIC PLANT SPECIES USED IN ANALYSIS

Acacia montis-usti Merxm. & A. Schreib.
Acanthosicyos horridus Welw. ex Hook. f.
Acrotome fleckii (Gürke) Launert
Adenia pechuelii (Engl.) Harms
Aeollanthus namibiensis Ryding
Aloe argenticauda Merxm. & Giess
Aloe asperifolia A. Berger
Aloe dewinteri Giess
Aloe dinteri A. Berger
Aloe erinacea D.S. Hardy
Aloe namibensis Giess
Aloe pachygaster Dinter
Aloe sladeniana Pole-Evans
Aloe viridiflora Reynolds
Anthephora ramosa Gooss.
Aristida effusa Henrard
Aristida hubbardiana Schweick.
Aristida parvula (Nees) De Winter
Asclepias buchenaviana Schinz
Boscia microphylla Oliv.
Boscia tomentosa Toelken
Brachiaria glomerata (Hack.) A. Camus
Brachystelma circinatum E. Mey.
Cadaba schroeppelii Suess.
Caesalpinia pearsonii L. Bolus
Capparis hereroensis Schinz
Centropodia glauca (Nees) Cope
Ceropegia dinteri Schltr.
Commiphora anacardifolia Dinter & Engl.
Commiphora capensis (Sond.) Engl.
Commiphora cervifolia J.J.A. van der Walt
Commiphora dinteri Engl.
Commiphora discolor Mendes
Commiphora giessii J.J.A. van der Walt
Commiphora glaucescens Engl.
Commiphora gracilifrondosa Dinter ex J.J.A. van der Walt
Commiphora kraeuseliana Heine
Commiphora multijuga (Hiern) K. Schum.
Commiphora namaensis Schinz
Commiphora oblanceolata Schinz
Commiphora saxicola Engl.
Commiphora virgata Engl.
Commiphora wildii Merxm.
Dombeya rotundifolia (Hochst.) Planch.
Dregeochloa pumila (Nees) Conert
Ehrharta pusilla Nees ex Trin.
Enneapogon scaber Lehm. var. *scaber*
Eragrostis aristata De Winter
Eragrostis kingesii De Winter
Eragrostis laevissima Hack.
Eragrostis macrochlamys Pilg.
Eragrostis omahakensis De Winter
Eragrostis pygmaea De Winter
Eragrostis sabinae Launert
Eragrostis scopelophila Pilg.
Eragrostis stenothyrsa Pilg.
Eragrostis walteri Pilg.
Erythrina decora Harms
Eulophia holubii Rolfe
Eulophia speciosa (R. Br. ex Lindl.) Bolus
Euphorbia avasmontana Dinter
Euphorbia chersina N.E. Br.
Euphorbia conspicua N.E. Br.
Euphorbia currorii N.E. Br.
Euphorbia damarana L.C. Leach
Euphorbia giessii L.C. Leach
Euphorbia gummifera Boiss.
Euphorbia gregaria Marloth
Euphorbia monteiroi Hook. f.
Felicia gunillae B. Nord.
Frankenia pomonensis Pohnert
Haemanthus avasimontanus Dinter
Hemizygia floccosa Launert
Hermannia glandulosissima Engl.
Hermannia merxmuelleri Friedr.-Holzh.
Hermannia stricta (E. Mey. ex Turcz.) Harv.
Hoodia montana Nel ex A.C. White & B. Sloane
Hoodia pedicellata (Schinz) Plowes
Isolepsis hemiuncialis (C.B. Clarke) J. Raynal
Kaokochloa nigrirostris De Winter
Lapeirousia avasmontana Dinter
Lapeirousia coerulea Schinz
Lavrania marlothii (N.E. Br.) Bruyns
Limonium dyeri Lincz.
Megalochlamys marlothii (Engl.) Lindau
Megaloprotachne glabrescens Roiv.
Merxmuellera rangei (Pilg.) Conert
Monechma calcaratum Schinz
Monechma callothamnum Munday
Monechma cleomoides (S. Moore) C.B. Clarke
Monechma crassiusculum P.G. Mey.
Monechma desertorum (Engl.) C.B. Clarke
Monechma grandiflorum Schinz
Monechma mollissimum (Nees) P.G. Mey.
Monechma tonsum P.G. Mey.
Monsonia ignorata Merxm. & A. Schreib.
Monsonia luederitziana Focke & Schinz
Nidorella nordenstamii Wild
Ozoroa insignis Delile
Pachypodium lealii Welw.
Panicum arbusculum Mez

Pechuel-Loeschea leubnitziae (Kuntze) O. Hoffm.
Pennisetum foermeranum Leeke
Pentzia tomentosa B. Nord.
Peristrophe grandibracteata Lindau
Peristrophe hereroensis (Schinz) K. Balkwill
Peristrophe namibiensis K. Balkwill
Plectranthus dinteri Briq.
Plectranthus unguentarius Codd
Plumbago wissii Friedr.
Raphionacme inconspicua H.E. Huber
Rikliella rehmannii (Ridl.) J. Raynal
Ruellia brandbergensis Kers
Sesamothamnus benguellensis Welw.
Sesamothamnus leistneranus Giess ex Ihlenf.
Setaria appendiculata (Hack.) Stapf
Setaria finita Launert
Sisymbrium dissitiflorum O.E. Schulz
Sporobolus engleri Pilg.
Sporobolus nebulosus Hack.
Stachys dinteri Launert
Stipagrostis amabilis (Schweick.) De Winter
Stipagrostis anomala De Winter
Stipagrostis brevifolia (Nees) De Winter
Stipagrostis damarensis (Mez) De Winter
Stipagrostis dinteri (Hack.) De Winter
Stipagrostis dregeana Nees
Stipagrostis garubensis (Pilg.) De Winter
Stipagrostis giessii Kers
Stipagrostis gonatostachys (Pilg.) De Winter
Stipagrostis hermannii (Mez) De Winter
Stipagrostis hochstetteriana (Beck ex Hack.) De Winter
Stipagrostis lutescens (Nees) De Winter
Stipagrostis namibensis De Winter
Stipagrostis ramulosa De Winter
Stipagrostis sabulicola (Pilg.) De Winter
Stipagrostis schaeferi (Mez) De Winter
Stipagrostis uniplumis (Licht.) De Winter
Strumaria phonolithica Dinter
Tricholaena capensis (Licht. ex Roem. & Schult.) Nees
Triraphis ramosissima Hack.
Wahlenbergia eriophiloides Markgr.
Welwitschia mirabilis Hook. f.

The ecology and conservation status of plant resources in Mozambique

S.O. BANDEIRA*, J.C. HATTON*, P. MUNISSE** and S. IZIDINE**

* Department of Biological Sciences, Faculty of Science, Eduardo Mondlane University, P.O. Box 257, Maputo, Mozambique.
** Department of Botany, National Institute of Agronomic Research, P.O. Box 3658, Maputo, Mozambique.

ABSTRACT

In terms of biogeographic affinities, approximately 80% of Mozambique is included in the Zambezian Regional Centre of Endemism. A broad band of the Zanzibar—Inhambane Regional Mosaic extends northwards along the coast from Xai-Xai (25°03'S) to the Tanzanian border (10°26'S). A small area of the Tongoland—Pondoland Regional Mosaic occurs on the south coast while small isolated areas of Afromontane elements occur on the highlands of central Mozambique.

The vegetation is characterized predominantly by miombo woodlands with large areas of mopane woodland in the Zambeze (Zambezi), Limpopo and Save (Sabi) valleys. Smaller areas of *Acacia* and nondifferentiated woodland occur in southern and central Mozambique respectively. Most of the protected areas of the country are located in these savanna woodlands: Gorongosa National Park, Banhine National Park, Zinave National Park, Rovuma Game Reserve, Maputo Elephant Reserve, Marromeu Game Reserve and the Zambezi Wildlife Utilization Unit. However, due to the war situation in the country, the infrastructure in these protected areas has largely broken down. The coastal zone is characterized by a mosaic of forest, woodland, swamp and mangrove habitats. The coastal forests are poorly documented but are believed to include a number of important endemic species, especially the northern coastal forests. Only a few small areas along the coast are protected (Bazaruto National Park, Pomene Reserve, and Inhaca Island Biological Reserve). The large-scale movement of refugees from the interior of the country to coastal zone areas due to the security situation has placed further pressure on these habitats. Species-rich montane forests are found on Mount Namuli, Mount Chipenene, the Njeji Plateau, Mount Gorongosa (outside the National Park boundary) and the Chimanimani Mountains. None of these montane forest areas are currently under protection status.

There is no *Red data book* for plants of Mozambique. Based on data published by IUCN and CITES, it is estimated that species of 60 genera may be threatened in Mozambique. However, these published data are mainly based on herbarium specimens and may not reflect the conservation status of plant species in the wild. This lack of information has been exacerbated by the war situation which has prevented botanical collection during the last 10 years. With the signing of the Peace Accord in October 1992, it may now be possible to document properly the conservation status of plant species and critical habitats throughout the country.

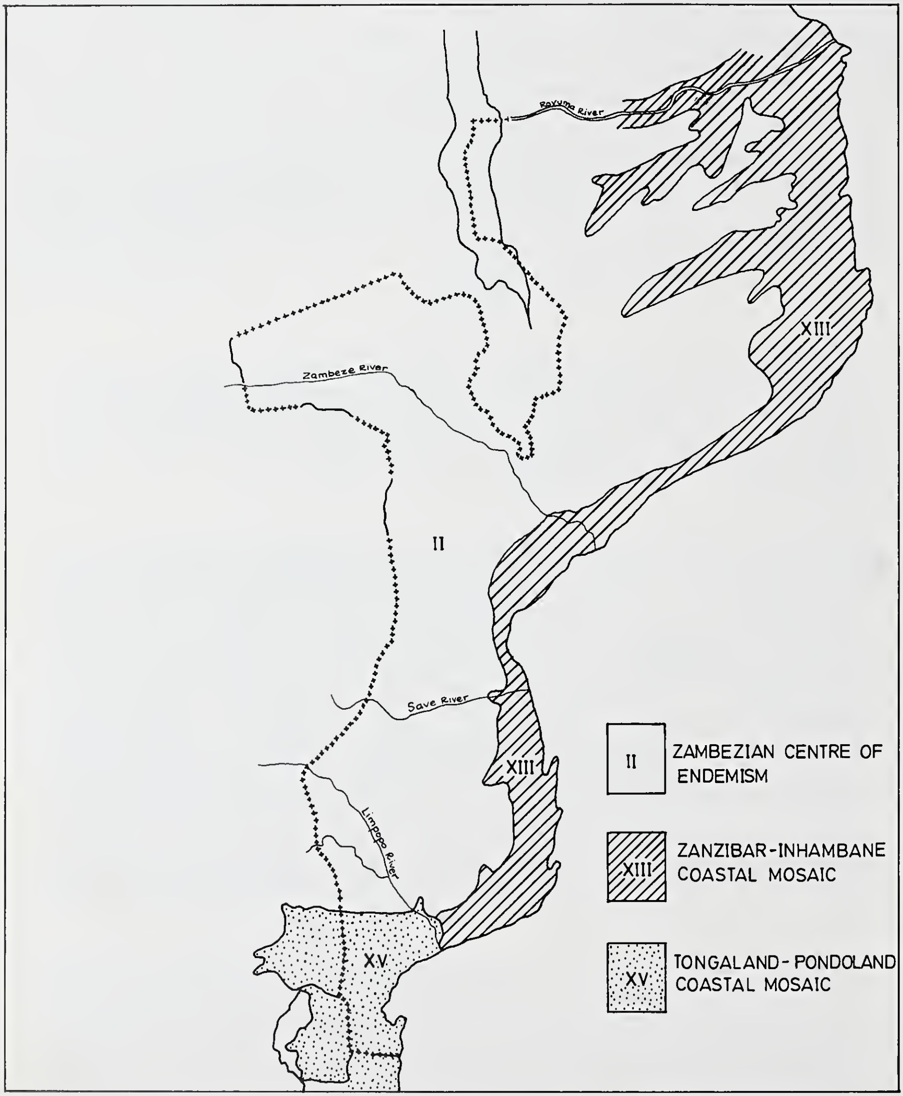

Figure 1.—Phytogeographic regions in Mozambique (after White 1983).

INTRODUCTION

Mozambique covers an area of 784 755 km^2 extending from Tanzania in the north (10°30′S) to Natal, South Africa, in the south (26°52′S). It is also limited by Malawi, Zambia, Zimbabwe, South Africa and Swaziland in the west and by the Indian Ocean in the east. The climate is both humid and dry, the annual mean temperature varying between 18 and 26°C, precipitation between 250 and 1 800 mm.

The three broad phytogeographic regions, namely the Zambezian Regional Centre of Endemism, Inhambane Regional Mosaic and Tongoland—Pondoland Regional Mosaic, are shown in Figure 1.

Seven broad vegetation types can be identified for Mozambique: miombo woodlands, the largest community dominated by *Brachystegia* spp. and *Julbernadia globiflora*; mopane woodland located along the Zambeze and between Save and Limpopo valleys dominated by *Colophospermum mopane*; undifferentiated woodland distributed along northern, central and southern Mozambique; Afromontane elements along the borders of both Zimbabwe and Malawi; coastal mosaics; halophytic vegetation along the Changane River, a tributary to the Limpopo River, is dominated by succulent creeping plants of *Arthrocnemum* sp., *Salicornia* sp., bushes of *Atriplex* sp., *Suaeda monoica* as well as *Acacia nilotica* and grass species; and swamp vegetation (Figure 2). Mangroves and intertidal forests are prominent on the coastline. They are dominated by exclusive species (*Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata*, *Avicennia marina*, *Lumnitzera racemosa* and *Sonneratia alba*) and nonexclusive species (*Acrosticum aureum*, *Arthrocnemum australasicum*, *A. indicum*, *A. perene*, *Barringtonia racemosa*, *Chenolea diffusa*, *Heritiera littoralis*, *Hibiscus tiliaceus*, *Pemphis acidula*, *Phoenix reclinata*, *Salicornia perrieri*, *Sesuvium protulacastrum*, *Suaeda monoica*, *Suriana maritima*, *Xylocarpus granatum*). Marine angiosperms and seaweeds comprise an important component of the flora of Mozambique, especially in economic terms. These communities together with the mangroves comprise an important component of the intertidal flora.

PROTECTED AREAS

A total of 89 602 km^2, covering 11.16% of the country's area, has protected area status and consists of national parks, reserves, wildlife utilization units (game reserves) and forest reserves (Direcção Nacional de Florestas e Fauna Bravia 1987; Cezerilo 1993) (Table 1). Despite this legislation, little protection is currently offered the fauna and flora of these areas due to the recent political situation. Therefore, new measures will have to be undertaken. Forestry reserves were created mainly to preserve indigenous trees. The Forest Reserve of Bobole, about 40 km north of Maputo, protects *Raphia australis*, known to be the most southern raffia palms in Mozambique; the Forest Reserve of Licuati, south of Maputo, protects pod mahogany, *Afzelia quanzensis*; the Forest Reserve of Goba protects

the Lebombo simbi tree, *Androstachys johnsonii*; the Forest Reserve of Inhaminga protects panga-panga, *Millettia stuhlmannii*; the Forest Reserve of Derre protects bloodwood, *Pterocarpus angolensis*. Figure 3 shows the distribution of these protected areas.

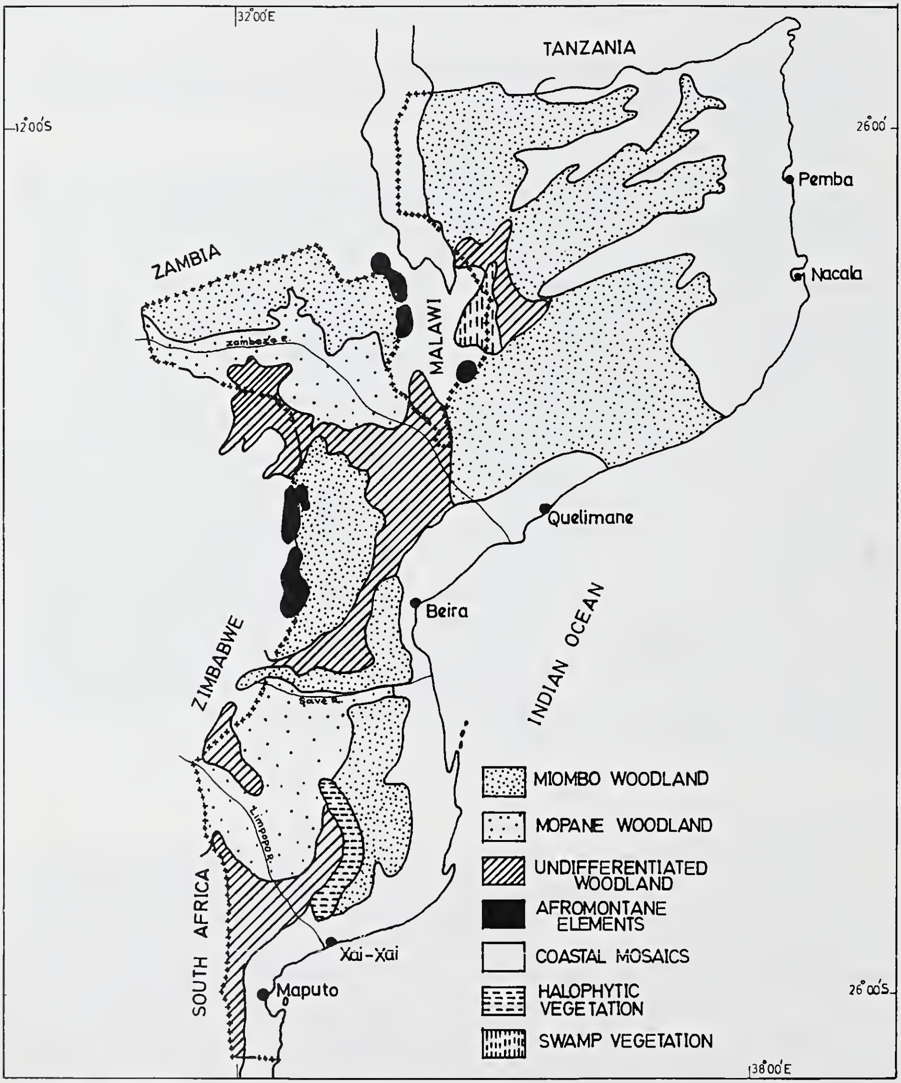

Figure 2.—Broad vegetation types in Mozambique.

TABLE 1.—The protected areas of Mozambique (total land area 784 755 km^2)

	Area (km^2)	Number	% of total area
National parks	16.220	4	2.03
Reserves	19.500	6	2.4
Wildlife utilization units (game reserves)	51.206	8	6.4
Forest reserves	2.676	16	0.33
Total	89.602	34	11.16

Source: Direcção Nacional de Floresta e Fauna Bravia (1987); Stuart & Adams (1990).

Apart from re-evaluating the present conservation measures, the legistation might be reinforced first to include more areas like those of Afromontane vegetation types; also, a national measure to conserve threatened species is needed. A rather concise legislation for trading indigenous timber was published in 1987 by the Direcção Nacional de Florestas e Fauna Bravia and it classified native wood into five categories (Table 2). This legislation also established rules for cutting different species according to diameter-at-breast-height criteria.

TRADITIONAL PLANT USE

Studies on the value of Mozambique's botanical diversity have been initiated comparatively recently, despite the extended history of traditional use of indigenous resources.

Most of the studies on plant utilization in the country documented information gathered from local people: Jansen & Mendes (1983a, 1983b, 1990, 1991). Maite (1987a, 1987b, 1991) dealt with the documentation of medicinal plants and De Carvalho (1968), Da Silva (1991) and Bandeira (1991) with nonmedicinal uses.

Plant uses tend to vary from one place to another since culture, language as well as plant distribution may vary. Mozambique encompasses more than 14 languages, some of them shared with neighbouring countries across its 3 000 km length. Diverse patterns of plant utilization can therefore be expected.

Indigenous plant use appears to follow similar patterns of utilization in neighbouring countries. Fuel and building materials represent the major consumption of plant biomass and tend to be used in a nonsustainable manner. Also, self-employment aiming at collecting and selling medicinal plants from the wild can rapidly threaten species like *Ansellia gigantea* mostly sold at Xipamanine Market in Maputo for the treatment of asthma. On the other hand, wild fruits and food plants may provide dietary supplements, especially in areas of low-potential agriculture as those around Maputo and on Inhaca Island.

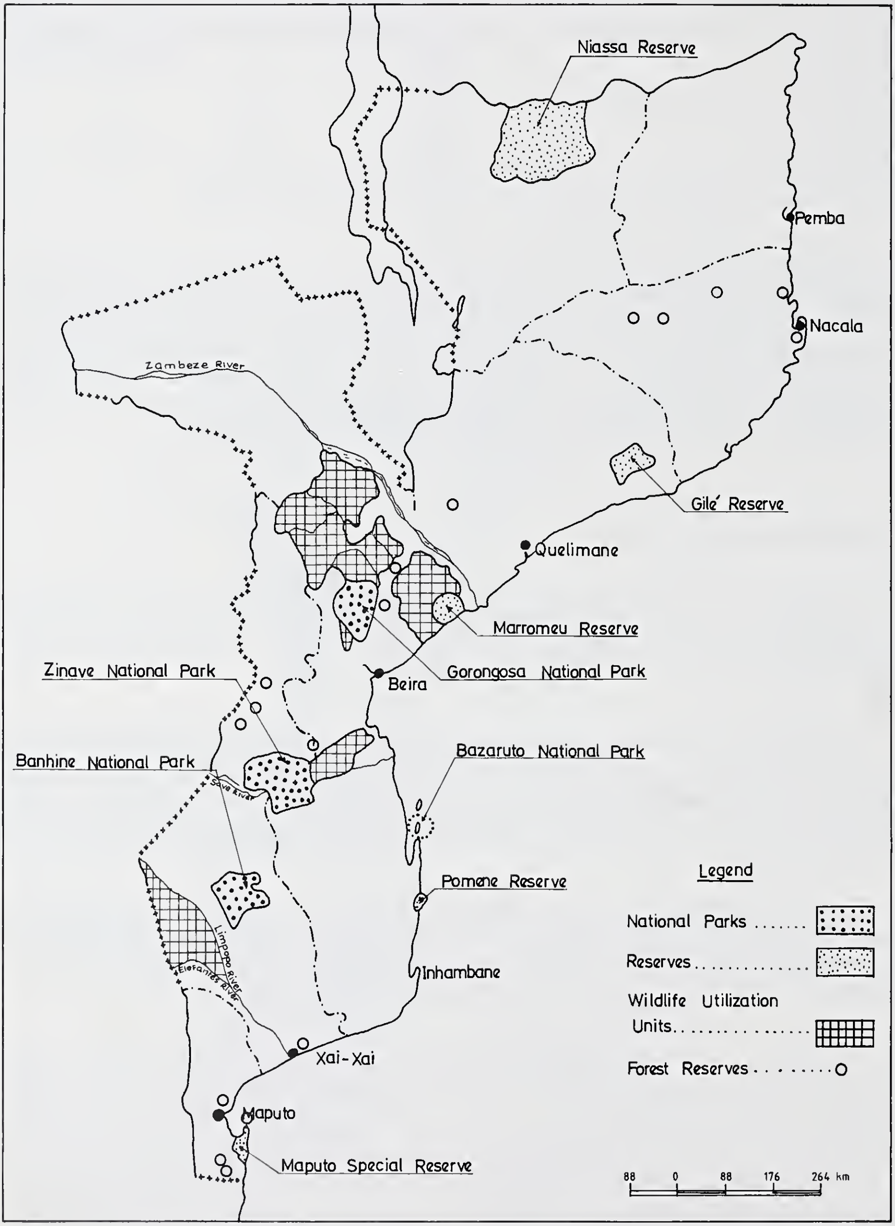

Figure 3.—Protected areas in Mozambique.

TABLE 2.—Categories (precious, first and second classes) of native wood, Mozambique.

Name	Family	Category
Berchemia zeyheri (Sond.) Grubov (red ivory, pau-rosa)	Rhamnaceae	Precious
Chlorophora excelsa (Welw.) Benth. & Hook. f. (mvule, tule)	Moraceae	Precious
Dalbergia melanoxylon Guill. & Perr. (blackwood dalbergia, pau-preto)	Fabaceae	Precious
Diospyros kirkii Hiem (pink diospyros, ebano africano)	Ebenaceae	Precious
Entandrophragma caudatum (Sprague) Sprague (wooden banana, mbuti)	Ebanceae	Precious
Ekebergia capensis Sparrm. (inhamarri)	Meliaceae	Precious
Guibourtia conjugata (Bolle) J. Léonard (small false mopane, chacate-preto)	Fabaceae	Precious
Spirostachys africana Sond. (sandalwood, sândalo)	Euphorbiaceae	Precious
Afzelia quanzensis Welw. (pod mahogany, chanfuta)	Fabaceae	1st class
Albizia versicolor Welw. ex Oliv. (poison-pod albizia, tanga-tanga)	Fabaceae	1st class
Androstachys johnsonii Prain (Lebombo ironwood, mecrusse, simbiri)	Euphorbiaceae	1st class
Balanites maughamii Sprague (small torchwood, nulo)	Balanitaceae	1st class
Breonadia microcephala (Delile) Ridsdale (mutimi, mugonha)	Rubiaceae	1st class
Cordyla africana Lour. (wild mango, mutondo)	Fabaceae	1st class
Erythrophleum africanum (Welw. ex Benth.) Harms (ordeal tree, missanda, muavi)	Fabaceae	1st class
Faurea speciosa (Welw.) Welw. (broad-leaved beechwood, muximi, nthethere)	Proteaceae	1st class
Inhambanella henriquesii (Engl. & Warb.) Dubard (inhambanella, mepiao)	Sapotaceae	1st class
Khaya nyasica Stapf ex Baker f. (red mahogany, umbaua, mbawa)	Meliaceae	1st class
Millettia stuhlmannii Taub. (jambire, panga-panga, pangiri)	Fabaceae	1st class
Morus mesozygia Stapf (African mulberry, mecobze)	Moraceae	1st class
Podocarpus falcatus (Thunb.) R. Br. ex Mirb. (Outeniqua yellowwood, gugojo, izulambite, chonguè, msongo, malatchen, um-koba)	Podocarpaceae	1st class
Pseudobersama mossambicensis (Sim) Verdc. (false white ash, tonduè, minhe-minhe)	Meliaceae	1st class
Pterocarpus angolensis DC. (bloodwood, umbila)	Fabaceae	1st class
Swartzia madagascariensis Desv. (snake bean, pau-ferro, naaquata)	Fabaceae	1st class
Albizia adianthifolia (Schumach.) W. Wight (flat-crown, mpepe, goane, megerenge)	Fabaceae	2nd class
Amblygonocarpus andongensis (Welw. ex Oliv.) Exell & Torre (Scotsman's rattle, mutiria, banga-wanga, mutindire)	Fabaceae	2nd class
Rhodognaphalon schumannianum A. Robyns (sumaúma, meguza, mfuma)	Bombacaceae	2nd class
Burkea africana Hook. (red syringa, mucarala, mucarati, mecimbi)	Fabaceae	2nd class
Julbernardia globiflora (Benth.) Troupin (messassa vermelha, mubimbi, mpakala)	Fabaceae	2nd class
Newtonia buchananii (Baker) Gilbert & Boutique (mafamuti, nipovera, forest newtonia)	Fabaceae	2nd class
Newtonia hildebrandtii (Vatke) Torre (Lebombo wattle, infomoze)	Fabaceae	2nd class
Pteleopsis myrtifolia (Welw. ex C. Lawson) Engl. & Diels (mungoroze, nduro, nleva)	Combretaceae	2nd class
Ricinodendron rautanenii Schinz (manketti tree, mungomo, ngomo, iphaka)	Euphorbiaceae	2nd class
Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro (canho, nkanye)	Anacardiaceae	2nd class
Sterculia appendiculata K. Schum. (tall sterculia, metil, njale)	Sterculiaceae	2nd class
Sterculia quinqueloba (Garcke) K. Schum. (large-leved sterculia, metonha, ntonha, ntchumpu)	Meliaceae	2nd class
Trichilia emetica Vahl (Natal mahogany, mafurreira, mafura, muciquimi)	Meliaceae	2nd class

Source: Direcção Nacional Floresta e Fauna Bravia (1987).

RED DATA BOOKS

Plant *Red data books* are very powerful tools for recording depletion or extinction of plant species as well as for sending this message to the public. There is no plant *Red data book* for the country as little plant collecting has been done in Mozambique. Table 3 is the first attempt to produce a *Red data* list for Mozambique and it was achieved using unpublished data and IUCN and CITES data (Grandvaux Barbosa 1968; Lucas & Synge 1978; Schouten 1992; World Conservation Monitoring Centre 1992). The list is not arranged according to IUCN categories. An analysis of herbarium voucher specimens and *in situ* observations might be the next step to improve this list. Information from neighbouring countries can also be used. *Warburgia salutaris*, *Encephalartos* spp., *Raphia australis*, *Ansellia gigantea* are some of the species in urgent need of protection.

TABLE 3.—Preliminary list of threatened plants of Mozambique

Taxon	Family	Taxon	Family
Aloe spp.	Liliaceae	*Guibourtia conjugata*	Fabaceae
Alsophila spp.	Cyatheaceae	*Habenaria* spp.	Orchidaceae
Angraecopsis spp.	Orchidaceae	*Liparis* spp.	Orchidaceae
Angraecum spp.	Orchidaceae	*Maerua* sp.	Capparaceae
Ansellia spp.	Orchidaceae	*Malaxis* spp.	Orchidaceae
Berchemia zeyheri	Rhamnaceae	*Microcoelia* spp.	Orchidaceae
Bonatea spp.	Orchidaceae	*Mystacidium* spp.	Orchidaceae
Brachycorythis spp.	Orchidaceae	*Neobolusia* spp.	Orchidaceae
Bulbophyllum spp.	Orchidaceae	*Pachypodium* spp.	Apocynaceae
Centrostigma spp.	Orchidaceae	*Pandanus* sp.	Pandanaceae
Ceropegia spp.	Asclepiadaceae	*Platycoryne* spp.	Orchidaceae
Chlorophora excelsa	Moraceae	*Platylepis* spp.	Orchidaceae
Cycas thouarsii	Cycadaceae	*Podocarpus* sp.	Podocarpaceae
Cynorchis spp.	Orchidaceae	*Polystachya* spp.	Orchidaceae
Cyrtorchis spp.	Orchidaceae	*Protea* spp.	Proteaceae
Dalbergia melanoxylon	Fabaceae	*Rangaeris* spp.	Orchidaceae
Diaphananthe spp.	Fabaceae	*Raphia australis*	Arecaceae
Diospyros kirkii	Ebenaceae	*Satyrium* spp.	Orchidaceae
Diospyros mespiliformis	Ebenaceae	*Schizochilus* spp.	Orchidaceae
Disa spp.	Ebenaceae	*Schwartzkopffia* spp.	Orchidaceae
Disperis spp.	Ebenaceae	*Solenangis* spp.	Orchidaceae
Ekebergia capensis	Meliaceae	*Spirostachys africana*	Euphorbiaceae
Encephalartos spp.	Zamiaceae	*Stenoglottis* spp.	Orchidaceae
Ensete ventricosum	Musaceae	*Strelitzia* sp.	Strelitziaceae
Entandrophragma caudatum	Meliaceae	*Tridactyle* spp.	Orchidaceae
Epipactis spp.	Orchidaceae	*Vanilla* spp.	Orchidaceae
Eulophia spp.	Orchidaceae	*Warburgia salutaris*	Canellaceae
Euphorbia spp.	Euphorbiaceae	*Widdringtonia* sp.	Cupressaceae
Faurea spp.	Proteaceae	*Xylopia* sp.	Annonaceae

Sources: Grandvaux Barbosa (1968), IUCN data, Schouten (1992) and unpublished data at LMU and LMA herbaria.

PLANT GENETIC RESOURCES

The high risk of losing valuable indigenous plant resources due to the deforestation for land preparation, collecting of firewood, timber and medicinal plants is a serious environmental problem in Mozambique, particularly in the heavily populated areas. Furthermore, crop genetic diversity and cultural erosion occur in this country due to the trend of introducing high-yielding varieties and modern farming technology which lead to the replacement of traditional varieties and indigenous farming technology. This has been exacerbated by frequent drought, war, hunger and, mainly, the distribution of seeds by relief programmes in the country (Ministério de Agricultura 1991). Crop land races and threatened plant species are priority targets for future collecting missions in Mozambique.

To address this important issue, the National Plant Genetic Resources Centre (NPGRC) was created as part of the Southern African Gene Bank whose primary function is to collect, conserve, document and promote utilization of the country's plant genetic resources.

Germ plasm collections in the country are shared by the National Plant Genetic Resources Centre (NPGRC), Centro de Experimentação Florestal (CEF), Instituto de Produção Animal (IPA), Sementes de Moçambique (SEMOC) and Secretaria de Estado para o Cajú (State Secretariat for Cashew Nut) (SEC) (Table 4).

INSTITUTIONS INVOLVED IN STUDYING PLANT BIODIVERSITY

Several institutions are involved in studying plant biodiversity and conservation: Section of Botany and Forestry Department, both at Eduardo Mondlane University (UEM); Department of Botany of the Instituto de Investigação Agronómica (INIA); Direcção Nacional de Florestas e Fauna Bravia (DNFFB); Comissão Nacional do Meio Ambiente (CNA); Centro de Experimentação Florestal (CEF) and the Instituto de Produção Animal (IPA).

Some of these are new bodies, e.g. the National Commission for Environment, and are therefore still little involved with plant biodiversity. DNFFB was created in

TABLE 4.—Germ plasm collections in Mozambique

Institutions involved	Number of accessions	Number of species	Number of clones
Crop species (NPGRC)	614	17	–
Forestry species (CEF)	69	29	–
Species for forage (IPA)	233	112	–
Sementes de Moç. (SEMOC)	?	?	–
Secretaria de Estado para o Cajú (SEC)	–	–	around 600
Total	916	158	around 600

Source: Rodrigues (1993).

TABLE 5.—The existing herbaria in Mozambique

	LMU (University Herbarium)	LMA (National Herbarium)
Number of specimens	40 000	62 000
Researchers	4	4
Technicians	7	9
Current studies	Medicinal plants Value of trees Sea grasses Index Seminum	Weed plants Food plants

TABLE 6.—The botanical gardens in Mozambique and respective specifications

	University botanical gardens	I.N.I.A. botanical gardens
Area	10 ha	15 ha
Number of species	~80	~85
Funds	< 800 US$ per year	none
Vehicle	none	none
Technicians	15	none

the 1980s aiming mainly at the management of fauna and flora resources. This institution is the CITES Management Authority for Mozambique.

The LMU Herbarium (at Eduardo Mondlane University) and LMA Herbarium (INIA), both in Maputo, are the only institutions involved in studying the taxonomy of plant biodiversity in the country today.

Each herbarium is part of a Botanical Section which also comprises a small developing botanical garden (see Tables 5 and 6 for specifications). In addition, the Botanical Section at INIA encompasses the newly established National Plant Genetic Resources Centre.

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Swaziland's plant diversity and its conservation

K.P. BRAUN* and G.M. DLAMINI**

* Swaziland National Trust Commission, P.O. Box 1797, Mbabane, Swaziland.
** Swaziland National Herbarium, Malkerns Research Station, P.O. Box 4, Malkerns, Swaziland.

ABSTRACT

A brief summary of plant collecting in the past in Swaziland is given, followed by an overview of current knowledge of plant species present in the country, their distribution and status. An example of collecting results from one area is presented to indicate the extent to which the country's plant biodiversity is known. Comments are made on the state of knowledge on endemic species.

An overview of the extent of *in situ* conservation of plant genetic resources in the country is given, followed by a summary of progress to date in the *ex situ* conservation programme. A summary is given of seed collecting activities for *ex situ* conservation, followed by brief comments on utilization of plant genetic resources from Swaziland.

INTRODUCTION

Swaziland is a relatively small country of just over 1 700 km^2, but it includes a great range in altitude, from about 120 m in the east to over 1 860 m in the northwest (Figure 1). It also has diverse geology and soils, and the climate varies considerably, with annual rainfall figures varying from 500 to over 1 500 mm. This diversity in physical attributes is reflected in the corresponding diversity in the flora.

The vegetation of Swaziland comprises bushveld, mixed grassland and sour grassveld, with the Veld Types represented in Swaziland, according to Acocks's (1988) classification, being Zululand Thornveld, Northeastern Mountain Sourveld, Lowveld Sour Bushveld, Lowveld, Arid Lowveld, Piet Retief Sourveld, Northern Tall Grassland, and small areas of Northeastern Sandy Highveld and Bankenveld to Sour Sandveld Transition. Within these areas habitats vary from open grassland to forest, and from semi-arid savanna to wetlands.

SWAZILAND'S PLANT DIVERSITY

Knowledge of Swaziland's plant diversity is based on the collection of herbarium specimens from throughout the country. This diversity is therefore known only at the species, subspecies or variety level, with little or no information available on genetic diversity within populations.

Plant exploration

Collection of plants from Swaziland was first carried out in 1886 by Ernest E. Galpin, soon after the commencement of goldmining in Barberton, and then in 1890, by a Mr Saltmarshe, who visited the Havelock area. The next collector in Swaziland was Dr Harry Bolus, in 1906, who collected plants in the Mbabane and Mbuluzi River areas. The first Swaziland resident to collect plants systematically was Miss Mabel Stewart, who collected a considerable number of plants in the Hlatikulu area in 1911 and 1912 (Compton 1976).

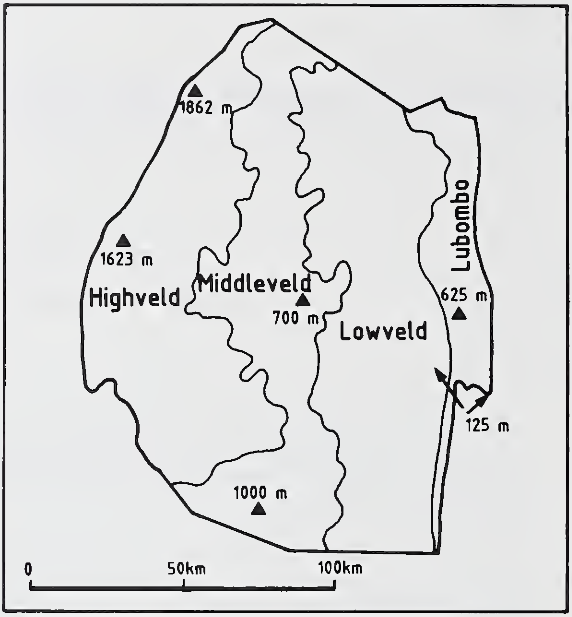

Figure 1.—Map of Swaziland, showing climatic zones and selected altitudes.

The first publication on Swaziland plants in *Flora* form was Dr J. Burtt Davy's *A manual on the flowering plants and ferns of the Transvaal with Swaziland, South Africa*, published in two parts in 1926 and 1932. Prior to the publication of these works only 217 species were recorded from Swaziland (Compton 1966).

The first intensive botanical survey of the country was carried out by Professor R.H. Compton who, on his retirement to Swaziland in the early fifties, collected intensively throughout the country, with assistance from Miss M.C. Karsten and Mr Ben Dlamini. This survey was carried out from 1955 to 1966, listing 2 350 species including the naturalized exotics (Compton 1966). This was followed by the publication of the *Flora of Swaziland* in 1976, containing descriptions and keys for 2 118 species (Compton 1976).

In 1975 a National Herbarium was established in Mbabane. The first Curator was Mrs Ellen S. Kemp, who carried out extensive plant collection. During the same period, intensive collection of what is now Mlawula Nature Reserve was undertaken by Mr James Culverwell. Ellen Kemp published *Additions and name changes for the flora of Swaziland* in 1981 (Kemp 1981), and this was followed by *A flora checklist for Swaziland* in 1983, listing 2 715 indigenous species and 110 naturalized exotics (Kemp 1983).

Plant collecting has been continued by various collectors, including the current Herbarium Curator, Mr G.M. Dlamini, who has covered most of the country. The nature reserves have been well collected by nature conservation officers.

Work is currently being carried out on revising the *Swaziland checklist*, with a provisional total of 2 400 species, of which 157 are naturalized exotics (Braun, in prep.). This includes the first listing of bryophytes, a group which still requires much collecting.

A comparison of the flora currently recorded for Swaziland with that of the *Flora of southern Africa* (Table 1), shows that despite its small size, Swaziland contains almost 14% of the taxa recorded from the region.

Extent of coverage of plant exploration

Although plant collecting has now been carried out over a number of decades, there are still areas that have not been intensively collected, and even in those areas where much collecting has been done, there are still species that have not been sampled.

This is illustrated by considering two neighbouring quarter-degree grid squares, 2631AA and 2631AB, situated in the northwest of the country. The number of specimens and species currently held by the National Botanical Institute (NBI) in Pretoria for these grid squares is 1 907 specimens of 1 177 species for 2631AA and only 94 specimens of 87 species for 2631AB (Figure 2). Although it might be expected that 2631AA would contain a higher plant diversity due to a greater diversity of geology, soils and altitudes than 2631AB, this only partly accounts for the low number of species recorded in the latter square.

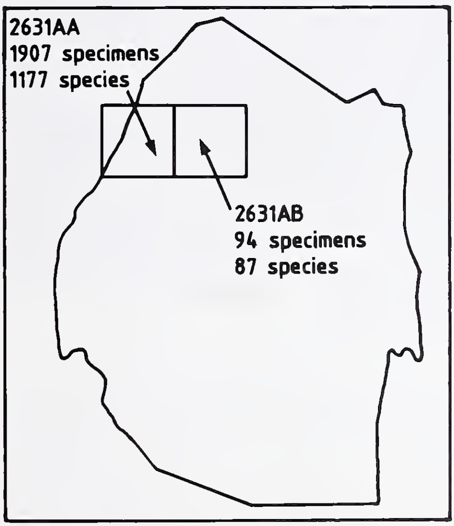

Figure 2.—Map of Swaziland showing quarter-degree grid squares 2631AA and 2631AB, indicating the number of specimens and species currently held by the National Botanical Institute, Pretoria.

The first square includes Malolotja Nature Reserve, as well as areas intensively sampled by Professor Compton, Ellen Kemp and other collectors. The second, 2631AB, is undersampled as it is relatively inaccessible. Therefore the differences between the two squares are largely due to differences in collecting intensity. These collections have been made over the past three years on sporadic trips including some with the staff of the NBI.

TABLE 1.—Comparison of Swaziland's flora with the flora of southern Africa

	Families		Genera		Species		Taxa		Subspecies		Varieties		Subspecies & varieties		Naturalized species	
	FSA*	SD**	FSA	SD	FSA	SD	FSA	SD	FSA	SD	FSA	SD	FSA	SD	FSA	SD
Bryophyta	94	44	292	80	814	133	817	133	3	0	11	0	0	0	0	0
Pteridophyta	28	22	76	43	260	92	282	101	7	2	41	20	0	0	12	2
Gymnospermae	7	4	8	4	50	11	52	11	2	0	2	0	0	0	10	1
Monocotyledonae	47	33	518	235	4 912	853	5 323	892	315	56	422	82	7	2	141	20
Dicotyledonae	177	129	1 710	732	16 175	2 149	18 029	2 264	1 118	225	2 104	267	92	16	695	157
(Angiospermae)	(224)	(232)	(2 228)	(967)	(21 087)	(3 002)	(23 352)	(3 156)	(1 433)	(281)	(2 526)	(349)	(99)	(18)	(836)	(177)
Total	353	232	2 604	1 094	22 211	3 238	24 503	3 401	1 445	283	2 580	369	99	18	858	180
% in Swaziland		65.7		42.0		14.6		13.9		19.6		14.3		18.2		21.0

* FSA = flora of southern Africa—data on flora of southern Africa from Arnold & De Wet (1993).
** SD = Swaziland flora—Swaziland data from provisional Swaziland checklist (Braun, in prep.).

The state of knowledge of the flora can also be illustrated by considering species endemic to Swaziland. In her 1983 publication, Ellen Kemp states that only four endemic species were known to her (Kemp 1983). Current investigations have to date confirmed that there are probably at least 25 endemic species, most of which had been collected prior to Ellen Kemp's publication. This increase in numbers has been in part due to new species being described, and is also the result of a literature survey.

DISTRIBUTION AND STATUS OF PLANTS WITHIN SWAZILAND

Very little is currently known about the distribution of plant species within the country. Although much information is available in the form of herbarium specimens, this is yet to be analysed, particularly as the National Herbarium is not yet computerized. Similarly, little is known of the status of most species. Some data on species distributions have been collected by the Forestry Section of the Ministry of Agriculture in the course of carrying out a Forest Inventory for the country (Hess *et al.* 1990). Furthermore species distribution data of members of the Proteaceae are being obtained through involvement with the southern African Protea Atlas Project.

With regard to the status of endemic plant populations, detailed surveys have been carried out for only one species, namely *Kniphofia umbrina*, which is restricted to an area of about 40 km^2. Most of the natural populations of this species are under threat, and various activities have been carried out in order to ensure the survival of this species, including establishment in botanical gardens, translocation to a nearby protected area, and

seed collection for long-term *ex situ* storage. Another endemic species, *Syncolostemon comptonii*, may be seriously threatened by the construction of a reservoir. At present it has been recorded only from within a ten-kilometre stretch of the Nkomati River valley, and at least half of this area is due to be inundated by the construction of a reservoir on this river. Little is known about the status of other endemic species, although partly by chance, some of them occur within existing protected areas.

SWAZILAND'S PLANT DIVERSITY IN AN INTERNATIONAL CONTEXT

The number of species recorded for Swaziland compared with areas of similar size (Table 2) indicates, as one might expect from the diversity of altitude and geology and from Swaziland's latitude, that the country contains a relatively high diversity of species. This pattern is not echoed by a high diversity of endemic species (Table 2).

IN SITU CONSERVATION OF PLANT DIVERSITY

In situ conservation of plant diversity in Swaziland is primarily within nature reserves. These include Malolotja and Mlawula Nature Reserves, run by the Swaziland National Trust Commission, the parastatal organization responsible for conservation in the country. In addition to these, there are private nature reserves and game sanctuaries, as well as Hlane Game Sanctuary, belonging to His Majesty the King. Although their objectives usually do not specifically include the conservation of plant diversity, these reserves provide some level of protection for the flora. There are also a number of private farms where a high floral diversity is protected. Other areas where the flora is protected by default, include the sites of royal graves at a number of localities in the country. There is also legislation which provides protection for certain plant species throughout the country, although enforcement of this legislation is often difficult.

TABLE 2.—Number of species and endemics of selected areas throughout the world of similar sizes to Swaziland (data from Major 1988)

	Area × 1 000 km^2	Latitude	Number of species	Number of endemics	Number of species per 1 000 km^2	% endemics
Pyrenees	12	41	720	103	60.0	14
Dzungarian Alatau	12	45	2168	76	180.7	3
New Caledonia	16	21	2700	2500	165.3	92
Hawaiian Islands	16	21	1897	1751	113.6	92
Swaziland	17	26	3238	25	190.5	1
Israel	20	31	2380	155	119.0	6
Kern County	21.2	35	1463	17	69.0	1
Nutratinski Mts & Kizylkim	25	66	983	43	39.3	4

TABLE 3.—Seed collecting activities carried out in Swaziland

Year	Organization*	Type of material	Number of accessions
1985?	SADC/ICRISAT	Sorghum land races and wild relatives	99
1985?	UNISWA	Wild and cultivated cucurbits	?
1988	IITA	*Vigna, Sphenostylis* & *Zea mays*	?
1989	IBPGR/SPGRC	Crop relatives and forage species	221
1991	Kew/SPGRC	Indigenous and naturalized species	55
1992	Kew/SPGRC	Indigenous and naturalized species	36
1993	SPGRC	Crop land races and wild relatives	?
1993	SPGRC	Indigenous species	58

* IBPGR, International Board for Plant Genetic Resources; ICRISAT, International Crops Research Institute for the Semi-Arid Tropic; IITA, International Institute of Tropical Agriculture, Ibadan, Nigeria; Kew, Kew Seed Bank, Wakehurst Place, England; SADC, Southern African Development Community; SPGRC, Swaziland Plant Genetic Resources Centre; UNISWA, University of Swaziland.

The potential of protected areas to protect Swaziland's plant species is illustrated by Malolotja and Mlawula Nature Reserves containing an estimated 60% of species recorded in the country. Although 60% of the taxa may be under protection, the two areas represent only 2% of the total area of the country, and can therefore contain only a limited amount of the infraspecific diversity of these plants. There is the further problem that although these are protected areas, this does not necessarily ensure the survival of all species within the area, as very little is known about the specific requirements of most species.

EX SITU CONSERVATION OF PLANT DIVERSITY

Ex situ conservation of plant diversity is slowly getting under way with the establishment of a National Plant Genetic Resources Centre in 1988 as part of the SADC regional programme (Moss 1994). Progress to date has included the allocation of a building and receipt of some equipment, although the centre is not yet operational. Seed collection activities have been under way for a number of years, with most of the indigenous plant material at present being kept in temporary storage in the Kew Seed Bank in England.

Seed collection has included both land races of crops and indigenous species (Table 3) from various localities within the country. In the mid-1980s, collection of sorghums, predominantly of land races, was carried out by SADC/ICRISAT, with 99 accessions being collected, and wild and cultivated cucurbits were collected by the University of Swaziland with funding from IBPGR. In 1988 indigenous vignas as well as a few accessions of *Sphenostylis stenocarpa* and *Zea mays* were collected by a team from IITA. In 1989, the IBPGR collector for southern Africa, in collaboration with the Swaziland Plant Genetic Resources Programme, collected 221 samples of crop relatives and forage species in Swaziland. This was followed in 1991 and 1992 by collecting trips carried out by the Kew Seed Bank in collaboration with the Swaziland Plant Genetic Resources Programme (Braun

& Prendergast 1992). Collection of crop land races and some wild relatives was carried out in 1993 by the SADC Regional Gene Bank in collaboration with the Swaziland Plant Genetic Resources Centre.

UTILIZATION OF PLANT GENETIC RESOURCES

Utilization of plant genetic material to date has been limited, but it includes material collected in Swaziland from a number of species including various *Vigna* species, used for plant breeding research by ORSTOM in Niger; *Stomatanthes africanus*, used for research into the biological control of *Chromolaena odorata* by the Department of Agriculture in South Africa; various bulbous plants used for research into ornamental plants by the Vegetable and Ornamental Plant Institute in South Africa, and *Sorghum* land races used in plant breeding programmes by SADC/ICRISAT. In addition, small quantities of seed from indigenous tree species have been collected for investigation for woodlots in a rural development programme run by Yonge Nawe, a local nongovernmental organization.

CONCLUSION

In conclusion, it can be seen that Swaziland contains a relatively high diversity of plant species. Although plant collecting has been carried out over a number of years, this has been by no means exhaustive, and much more collecting needs to be done. There is a need to compile information on distributions from existing data, as well as to conduct further field investigations in this regard. Much research is needed into the status of plant species in the country, in order that steps can be taken to protect threatened species. *Ex situ* conservation and utilization of plant genetic resources have recently been initiated.

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Identifying and describing areas for vegetation conservation in Zimbabwe

J.R. TIMBERLAKE* and T. MÜLLER**

* Chesa Research Station, P.O. Box 467, Bulawayo, Zimbabwe.
** National Herbarium, P.O. Box CY550, Causeway, Harare, Zimbabwe.

ABSTRACT

Zimbabwe has a relatively large percentage of its land under National Parks and Safari Areas, but these protected areas have, in most cases, been primarily chosen for their large mammal populations. Therefore conflicts can arise between the damage caused by large mammals (especially elephant) and the desire to maintain high plant biodiversity and conserve relatively pristine habitats. It is pointed out that biodiversity also incorporates the diversity of ecological processes, many of which are threatened with simplification due to high herbivore pressures.

After describing the existing network of protected areas in Zimbabwe, the paper discusses the two major approaches to botanical conservation that could be followed. One approach concentrates primarily on unusual, spectacular, rare or endemic species, and the other focuses on conserving examples of the complete range of vegetation types and ecosystems. A hierarchical framework is proposed, and four areas of high vegetation and habitat diversity (the highest level of the hierarchy) in the country are described along with other, smaller areas of conservation interest. Future work necessary to obtain a representative selection of the country's biodiversity is outlined.

INTRODUCTION

The identification and protection of areas for nature conservation, or (one might now say) biodiversity conservation, has been a topic of discussion in Zimbabwe for many years, but much, perhaps too much, of the debate and action has focused on suitable extensive areas for conservation of large mammals. Indeed, the present network of National Parks and Safari Areas reflects this.

There are essentially two approaches to botanical conservation. One concentrates primarily on unusual, spectacular, rare or endemic species, or areas of high species diversity and endemism, while the other concentrates on the conservation of examples of all major vegetation types and ecosystems (Müller 1993). The first is the traditional approach practised all over the world; the second is often neglected, but is absolutely necessary if comprehensive *in situ* conservation of plant genetic resources is to be achieved. The less diverse vegetation types, for example the extensive but relatively dull types such as miombo and mopane woodland, contain plants which are not represented in the more species-rich habitats, and together they amount to a wealth of genetic resources which will be

lost if no attention is paid to their conservation. Good progress has been made with the first approach in Zimbabwe, and a significant portion of the flora is now adequately protected, especially if one adds the many species occurring in mountainous country protected by inaccessibility. When it comes to the second approach, namely the conservation of ecosystems and vegetation types, the situation is extremely dismal. For instance, practically all vegetation types which occurred on arable land on the central plateau or highveld have been destroyed by commercial farming, and in some of the communal lands even vegetation types on nonarable land are now degraded beyond reasonable recovery. At present most development is taking place in less populated areas in the north of the country, much of it on land recently cleared of tsetse fly. It is here that the destruction of natural vegetation is at its most active and some unusual or unique vegetation types are in acute danger of extinction.

Perhaps the major problem in ensuring adequate protection for indigenous vegetation is the rapid rate of land development in some parts of the country, coupled with the lack of a voice for biodiversity conservation in the planning process. Another major problem is damage to vegetation by large herbivores such as elephant, particularly in National Parks and Safari Areas. Many trees have been destroyed or reduced to shrubs by these animals, encouraging the expansion of grass cover, which in turn increases the risk and impact of fire, as can be seen on the Zambezi escarpment. The diversity of species present in an area may not decrease markedly with increased herbivore pressure, although the vegetation structure and the relative species frequency are often greatly modified. However, biodiversity also includes the diversity of ecological processes. Biodiversity can thus be reduced by virtue of the destruction, modification or speeding up of these processes under such pressure. However, this aspect of biodiversity conservation is not discussed further here.

In this paper we give brief descriptions of some of the major areas of interest identified so far, and point out what has already been conserved and what still remains to be done. The paper is based on an earlier article by Müller & Timberlake (1992).

EXISTING PROTECTED AREAS

Zimbabwe has nine types of Protected Areas (Table 1) of which only five are particularly important for vegetation conservation. The best known Protected Areas (including National Parks, Safari Areas and Botanical Reserves) fall under the jurisdiction of the Department of National Parks and Wildlife Management. Three groups of forest area are under the jurisdiction of the parastatal Forestry Commission, while the Department of Natural Resources is responsible for 18 Defined Areas, each of relatively small size. Plantation Forests, Recreational Parks and Wildlife Sanctuaries are not primarily for conservation of vegetation but, even excluding these categories, Zimbabwe still has almost 55 000 km^2 (over 14% of the country) where biodiversity conservation is stated to be the major land use.

TABLE 1.—Protected Areas in Zimbabwe

Type	km^2	% of country
Protected Forest (communal land)	608.3	0.16
Indigenous Forest (Forestry Commission)	8 392.4	2.15
Plantation Forest (Forestry Commission)	787.1	0.20
National Parks	27 039.1	6.92
Safari Areas	18 919.2	4.84
Recreational Parks	3 487.4	0.89
Wildlife Sanctuaries	161.4	0.04
Botanical Reserves	16.7	0.004
Defined Areas (Natural Resources)	n/a	n/a
TOTAL	59 411.6	15.20

Some National Parks are managed primarily for their vegetation and scenery, such as those of the Eastern Highlands (Chimanimani and Nyanga), and a network of 25 Botanical Reserves was set up in 1975 under the Parks and Wildlife Act (Robertson 1986) specifically to conserve areas of special botanical interest. Each one is of relatively small size, generally 10 to 200 ha, but in 1979 some were degazetted (presumably reflecting partial destruction or degradation) and at present there are only 14. However, most of Zimbabwe's protected area, such as Protected Forest, Indigenous Forest and Safari Areas, is utilized for products such as timber or sport hunting, but with conservation and sustainability as a guiding factor.

Looking at the network of conservation areas and comparing it to the vegetation map of Wild & Barbosa (1968), it can be seen that most vegetation types are included, but some (Table 2) are poorly represented or not at all. The four types of major importance are *Brachystegia spiciformis–Julbernardia* woodland, *Parinari curatellifolia* tree savanna, *Acacia* tree savanna and *Andropogon* grassland on serpentine (the Great Dyke). The *B. spiciformis–Julbernardia* woodland in particular covers roughly 16% of the country yet is poorly represented in gazetted conservation areas, as is the unique vegetation of the Great Dyke with its 20 to 30 endemics. However, this vegetation map is rather generalized and is not a particularly good guide to the full range of vegetation types in the country. Further vegetation survey is still needed to reveal the full status (Müller 1993).

APPROACH TO AREA IDENTIFICATION

A hierarchical arrangement has been adopted in the identification of areas for botanical conservation, as shown in Figure 1. This does not necessarily refer to the importance of any particular area for conservation, but reflects the scale of interest and the

TABLE 2.—Vegetation types not or poorly represented in gazetted conservation areas in Zimbabwe (following Wild & Barbosa 1968)

Brachystegia spiciformis–Julbernardia woodland
Parinari curatellifolia tree savanna
Terminalia sericea tree savanna
Acacia spp. tree savanna
Adansonia-Sterculia-Cordyla tree savanna
Colophospermum shrub savanna on basalt
Andropogon grassland

size. In the first category are areas of international significance with high ecosystem, vegetation type, habitat and species diversity within an area of between 500 and 2 500 km^2. In the second category of the hierarchy are areas in which specific ecosystems or vegetation types (preferably two or three together) are conserved, and are usually between 5 and 100 km^2 in size. The third category includes sites of particular biological interest which protect individual threatened species, areas of particularly well developed pristine vegetation (e.g. old burial sites) or outliers of locally rare vegetation due to environmental anomalies. These are generally small (0.1 to 5 km^2), and some could also be used as recreational areas, or for sustainable exploitation of minor products such as traditional medicines.

It is important to mention here that for the proposed areas, especially those in the first level of the hierarchy, not all of the land has to be formally protected or gazetted as State Land, although that may be the most desirable option. For the areas described below, for instance, their extent is greater than the presently gazetted National Parks or Safari Areas that form their ‘core’, so as to include a more comprehensive range of biodiversity. But such surrounding land should be subject to strong planning constraints on any land use or developments that may be detrimental to biodiversity conservation.

Identification and documentation of conservation areas under the above scheme are still far from complete, especially for those areas falling into the second and third categories. The process of identification has still to be vigorously pursued. However, four areas of high ecosystem and species diversity (category 1), which are also of international significance (and in two cases contain a good number of endemic species), have been identified, and are briefly described below. The major part of them is already conserved in National Parks. Their distribution is shown in Figure 2.

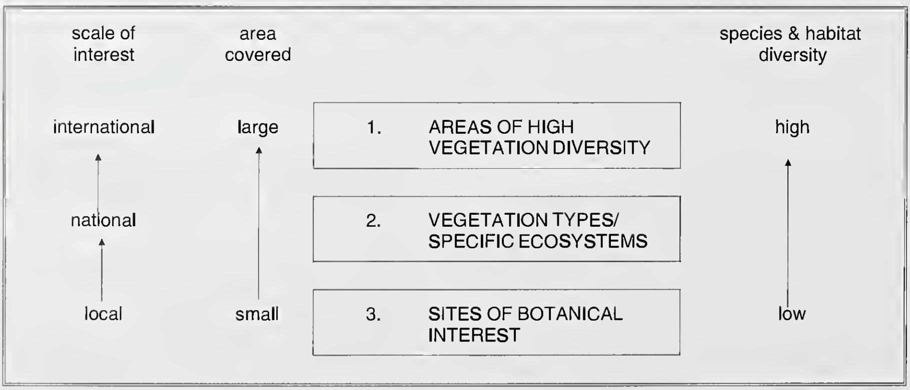

Figure 1.—Attributes of the hierarchical system of botanical conservation.

AREAS FOR VEGETATION CONSERVATION IN ZIMBABWE

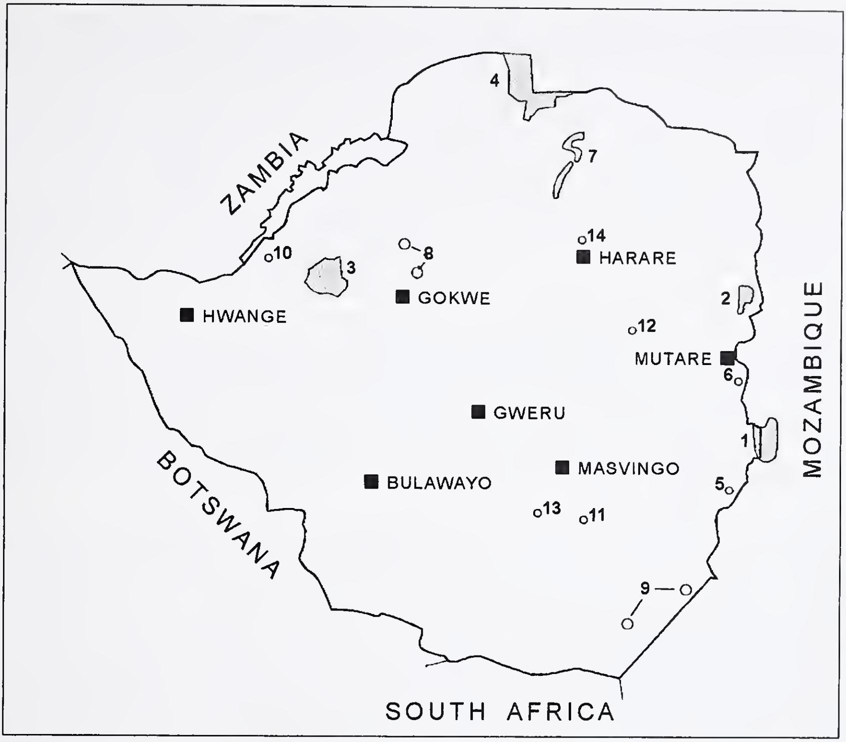

Figure 2.—Areas for vegetation conservation in Zimbabwe. 1, Chimanimani Mountains; 2, Nyanga Mountains; 3, Busi-Sengwa; 4, Chewore-Angwa; 5, Chirinda Forest; 6, Bunga Forest; 7, Great Dyke; 8, Gokwe dry forest; 9, Gonarezhou thicket; 10, Binga dry forest; 11, Nyoni Hills; 12, Mt Hwedza; 13, Mt Buhwa; 14, Mazoe Botanical Reserves.

PROPOSED CONSERVATION AREAS

Chimanimani Mountains

A rugged area of pristine beauty, 1 000 km^2 in extent and mostly in Mozambique, with high ecosystem diversity ranging from lowland forest (350 m altitude) to upland grassland (2 400 m) with many endemics. The high diversity results from the large altitudinal range, the differences in moisture availability due to locally high rainfall and interception of moist oceanic air on the eastern side, and the impoverished quartzite soils.

Most of the high-altitude plateau (1 500–1 800 m) comprises flattish grassland and scrub vegetation on schist, and a fynbos-like shrub and patches of grassland with a more diverse herbaceous flora on quartzite ridges, including many en-

demics (Goodier & Phipps 1962; Phipps & Goodier 1962). High-altitude or montane forest (*Widdringtonia nodiflora, Podocarpus latifolius, Schefflera umbellifera, Ilex mitis, Macaranga capensis*), verging to shrub, is found from 1 500 m upward, often in sheltered ravines. Small pockets of species-rich submontane forest occur in less accessible areas further down, and include *Craibia brevicaudata* and *Chrysophyllum gorungosanum.* On steeper quartzite slopes *Brachystegia microphylla* woodland is found, while on the gentle slopes on schist *Brachystegia spiciformis* woodland occurs. Towards the base of the mountains in the south and east and in low-lying valleys there are patches of lowland rainforest (*Newtonia buchananii, Khaya anthotheca, Erythrophleum suaveolens, Xylopia aethiopica, Maranthes goetzeniana* and stilt-rooted *Uapaca guineensis*), with *Millettia stuhlmannii* on the ecotones. Of the 859 species recorded above 1 200 m (Goodier & Phipps 1961), 50 to 60 are endemic (Wild 1964; R.B. Drummond pers. comm.), and various others are at the limits of their distribution. Dutton & Dutton (1973) recorded 103 woody species from lowland rainforest in Mozambique, and a checklist of the Haroni-Rusitu-Makurupini lowland rainforest area shows 637 species (R.B. Drummond pers. comm.). The total number of species found in the area probably exceeds 1 200.

Most of the area in Zimbabwe falls within Chimanimani National Park (171 km^2) and all of the main vegetation types are represented in it, including 2 km^2 of lowland rainforest along the lower Haroni River. The latter (often referred to as the Makurupini forest), together with the nearby Haroni and Rusitu Forest Botanical Reserves (totalling 170 ha), is the largest area of lowland rainforest remaining in Zimbabwe. The status of similar forests in Mozambique is not known. Much of the Rusitu valley below Nyahodi was previously a mosaic of moist primary and secondary forest following shifting agricultural practices, going through a broad transition to miombo on the ridges, but much of this has been removed due to high population pressure (Timberlake 1994). The proportion of cultivated land compared to regenerating forest has rapidly increased over the last 30 years on the Zimbabwe side of the Rusitu River, and this is now also occurring in Mozambique. Although the Chimanimani massif is currently well protected in Zimbabwe, management objectives may have to be modified in the long term. In Mozambique only two Forest Reserves, some distance away from the mountains and totalling 120 km^2, are protected, but there have been various proposals for gazetting a National Park (Dutton & Dutton 1973) over the whole area. Efforts will be needed to ensure complete protection of the Mozambican side of the Chimanimani Mountains and the adjacent lowland forests. Uncontrolled burning of the upland grassland is widespread on both sides of the border, but does not appear to be a problem; indeed it may encourage some of the endemics.

Nyanga Mountains

A very scenic area of around 600 km^2 of upland grassland, interspersed with a fynbos-like vegetation on the summit plateau, unique dwarf *Brachystegia spiciformis* woodland, moist montane forest and patches of medium- and low-altitude rainforest in the Honde and Pungwe valleys. Centred on the Nyangani

massif, the area ranges in altitude from 2 592 m (Mt Nyangani) to 700 m in the Pungwe valley. The high diversity results from the large altitudinal range and differences in available moisture due to aspect, but the area is less rugged and more affected by man than the Chimanimani Mountains. It contains the best continuous altitudinal range of moist forest types in the country (Müller 1991), from fairly extensive montane to smaller patches of medium altitude forest. There is also a small, practically pristine, medium-low-altitude rainforest at the base of Mtarazi Falls (1 200 m), the only locality in Zimbabwe for *Aningeria adolfi-friedericii*, and extremely small and much-threatened patches of low-altitude forest at Pungwe Bridge and Rumbisi Hill (700 m).

The grassland (1 800–2 100 m) is mostly of *Loudetia simplex*, *Themeda triandra* and *Eragrostis acraea* with *Pteridium aquilinum*, various *Helichrysum* species and shrubs of *Erica* (*Philippia*), *Stoebe vulgaris, Cliffortia* spp., *Leucosidea sericea* and *Passerina* spp. (Figure 3). The summit plateau of Mt Nyangani has a rich herbaceous flora including a few endemics (perhaps 5 to 10 species, R.B. Drummond pers. comm.) with a fynbos-like vegetation interspersed with small wetlands and rocky grasslands. Much of this is thought to be a relic of Gondwanaland times. Dwarf *Brachystegia spiciformis* woodland is found at the altitudinal limit of miombo, and was possibly previously more widespread from 1 700 to 2 000 m.

Figure 3.—Montane grassland with patches of high-altitude moist forest. Nyanga National Park.

Widdringtonia nodiflora shrub forest occurs in rainshadow areas on drainage lines, and can widen into a drier evergreen forest type, but better developed and more extensive rainforests are found on moist eastern windward slopes. The highest forests (2 100 m) contain *Syzygium masukuense, Podocarpus latifolius* and *Afrocrania volkensii*, while lower down (1 700 m) species such as *Olea capensis* and *Syzygium guineense* subsp. *afromontanum* are characteristic. Lower still (1 000 m), submontane species are found such as *Chrysophyllum gorungosanum, Trichilia dregeana, Craibia brevicaudata* and *Strombosia scheffleri*. The isolated lowland forests, some now impoverished, contain *Newtonia buchananii, Xylopia aethiopica* and *Maranthes goetzeniana*. In the Pungwe valley to the east, away from the mountains and on sandy soil, a low-altitude miombo woodland is found consisting of *Brachystegia utilis* and *Uapaca* species, a vegetation type more widespread in Mozambique. The species list for the whole area is incomplete, but should exceed 1 000.

The area comprises the Nyanga National Park (including the extension recently acquired around Gleneagles), a small private nature reserve, parts of the Eastern Highlands and Aberfoyle tea plantations and a small area of Holdenby communal land. Most is protected within the National Park, but the proposed centre extends beyond this to include small lowland forest patches and *B. utilis* woodland. An important threat to the upland grassland is invasion by *Pinus patula* and wattle (*Acacia mearnsii*). Forest edges are affected by burning, although this does not appear to have much reduced the extent of forest and is also necessary to maintain some of the grassland flora. Medium- and low-altitude rainforest areas are extremely rare and most have been destroyed by clearance for plantation crops such as tea and small-scale agriculture. There are, however, some small areas of regenerating forest in the Pungwe valley. Most of the low-altitude miombo woodland is now confined to nonarable areas, but is increasingly under threat as population pressures build up.

Busi-Sengwa

An area of 1 400 km^2 situated in north central Zimbabwe on the upper reaches of the Busi River (700–1 000 m altitude) encompassing grassland, mopane and miombo woodlands, various types of dry forest, and riverine woodland (Cumming 1970; Timberlake *et al.* 1993). The area is notable for its high habitat and vegetation diversity resulting from a broad range of underlying rock types and clear differences in topography and soils, particularly those developed from Karoo sediments. There are also river terraces of various ages and rocky gorges. It is the interface between the central plateau (highveld) and the Zambezi valley, and is sometimes termed middleveld.

The plateau at 1 000 m has *Brachystegia boehmii–Julbernardia globiflora–Pterocarpus angolensis* miombo woodland, with dry forest containing *Baikiaea plurijuga* and *Entandrophragma caudatum* on sandy colluvial slopes below. At the base (900 m) *Colophospermum mopane* woodland (Figure 4) is found with areas of *Setaria* grassland on clay. Scattered areas of dry *Combretum–Pterocarpus*

Figure 4.—*Colophospermum mopane* woodland showing signs of elephant damage. Sengwa wildlife research area.

lucens–Meiostemon tetrandus forest (often termed 'jesse bush' when degenerated into thicket) occur on shallow sands derived from Upper Hwange sandstone, while dry forest containing *Colophospermum mopane* and *Acacia robusta* is found on isolated patches of old alluvium. Such dry forests are very varied in their composition and structure, and this may in part be due to damage by elephant. More recent alluvium associated with larger rivers supports an open woodland of *Faidherbia albida* and *Trichilia emetica*. Also associated with these rivers are gorges containing species normally found in moist forests, such as *Anthocleista grandiflora*. A provisional woody species list contains 230 species and total species probably exceed 600. Some species are at the extreme southern or western limits of their distribution while others are of very local occurrence.

Most of the area is protected by the Department of National Parks and Wildlife Management. It consists of the southern portion of Chizarira National Park (270 km^2), Sengwa Wildlife Research Area (373 km^2) which is used for research purposes, and a portion of Chirisa Safari Area (430 km^2) which is used only for safari hunting. The remaining part (330 km^2) is in Busi communal land where cultivation and land-use pressures are now increasing, particularly on the dry forests on alluvium and on grasslands. Elephants cause major damage to vegetation structure, in particular to the miombo woodland and dry forest, and some form

of exclosure will be necessary to allow these vegetation types to return to their full stature. Such dry forests are unique to southern Africa and are now acutely endangered. Uncontrolled fire is also a threat, especially in miombo woodland.

Chewore-Angwa

An area of 2 400 km^2 situated in the main part of the mid-Zambezi valley, one of the last wilderness areas where vegetation is at its most diverse due to inaccessibility and a range of geological strata and soils. It is centred on the Chewore Hills and lower reaches of the Angwa and Manyame Rivers (350–1 000 m altitude) adjacent to the Mozambique border, and contains escarpment and lowland vegetation types including various types of dry forest, alluvial woodland, mopane woodland and several types of unusual dry miombo woodland (Du Toit 1993; Timberlake & Mapaure 1992). The *Xylia torreana–Pteleopsis myrtifolia–Entandrophragma caudatum–Combretum* spp. dry forests on sand include the best remaining examples of this type in Zimbabwe, and *Terminalia brachystemma* bushed woodland, unique to this area, is also included. Dry forest on alluvium is generally dominated by *Colophospermum mopane*, *Kirkia acuminata*, *Pterocarpus lucens* and *Commiphora caerulea*, and 'cathedral' mopane woodland (16–20 m) is also found. On more recent alluvium *Faidherbia albida* woodland is common, and has been less disturbed than in many other parts of the Zambezi valley, while the Chewore Hills contain *Julbernardia globiflora–Brachystegia allenii* woodland. An unusual, open, stunted miombo–mopane woodland with *Colophospermum mopane*, *Diospyros kirkii* and *Combretum apiculatum* is extensive on shallow soils. There are no endemics, but some species are at the limits of their distribution and others are restricted to the Zambezi valley. A comprehensive species list is not yet available.

Much of the area lies within Dande communal land (including the majority of the dry forests and riverine vegetation), but settlement is concentrated along the Manyame River, where vegetation on old alluvium, the best developed and most extensive known in Zimbabwe, is being rapidly destroyed by resettlement schemes. However, the rest of the northern Dande is used for safari hunting under the CAMPFIRE programme and so is reasonably protected. The remainder of the area described is already conserved under the Department of National Parks as Chewore and Dande Safari Areas. Apart from rapid clearance of dry forests and woodland on old alluvium (over 50% of this has been cleared here in the last 6 to 8 years), the greatest problem is elephant damage and, because of the removal of trees in the miombo woodlands, fire. Possibilities of extraction of oil and uranium mining may pose a threat in the future.

CONSERVATION OF VEGETATION TYPES

Work on the identification and description of conservation areas within each of the country's vegetation types (which can also be termed 'witness stands'), the second category in the hierarchy given above, is still far from complete. We need to look carefully at what is already conserved, and identify specific examples of

vegetation types that are not yet protected. Certain species-rich vegetation types are particularly threatened, such as the medium- and low-altitude moist forests of the Eastern Highlands, the low-altitude dry forests (sometimes termed 'jesse bush') of the Zambezi and Save/Limpopo valleys, and the riparian woodlands developed on alluvium flanking larger rivers. A systematic approach with a national perspective must be followed in order to identify the best possible areas and bring these to the attention of planners. This is perhaps best done by a national vegetation survey such as has been started for the communal lands (Timberlake *et al.* 1993).

Many vegetation types are found on land managed by the Department of National Parks and Wildlife Management, and here the problem is often to change some of the management practices to ensure that examples of these vegetation types are protected from damage caused by large mammals and fire (which is often consequent on such damage). Some areas of particular interest, outside of the National Parks Estate, have been known for a long time and are formally protected (e.g. Chirinda Forest near the southeast border with Mozambique), while others remain to be identified. It is these latter areas that could be damaged or destroyed unwittingly. A selection of areas already identified, some of which are not yet protected, is shown in Figure 2. In the descriptions which follow, each area has been assigned a number, marking its location in Figure 2.

Chirinda Forest (5) is the largest area (606 ha) of medium-altitude moist forest in the country, a unique and well documented assemblage of species from high and low altitudes on the tops of two hills protected by the Forestry Commission (Timberlake 1993). The canopy is up to 50 m high and comprises *Chrysophyllum gorungosanum*, *Craibia brevicaudata* and *Trichilia dregeana*. Other important species are *Khaya anthotheca*, *Lovoa swynnertonii* and *Newtonia buchananii*. Bunga Forest (6) in the Vumba Mountains south of Mutare, is another reasonably sized patch of medium-high-altitude moist forest containing *Syzygium guineense* subsp. *afromontanum* and is protected as a Botanical Reserve by the Department of National Parks.

The Great Dyke (7) is a unique geological formation running across the country with a distinctive flora (Barclay-Smith 1964; Wild 1965) and over 20 endemics (R.B. Drummond pers. comm.). Although there is some regional variation between the northern and southern portions of the Dyke, the major area proposed for conservation is in the north in the Horseshoe area of Guruve, and includes the full range of vegetation types, most of the endemics and *Raphia farinifera* palms. Only the Raphia Botanical Reserves (totalling 324 ha) are presently protected.

The Copper Queen dry forests or thickets (8) in eastern Gokwe are dominated by trees of *Xylia torreana* with a dense layer of *Combretum celastroides* and *C. elaeagnoides*, and contain some very unusual species for Zimbabwe, as well as good stands of *Entandrophragma caudatum* (Timberlake *et al.* 1993). Their extent has diminished over the years with increasing pressure for cultivation, and many are now being slowly cleared. At present they cover no more than 30–50 km^2, and are in small fragments. The only protected areas are in the Forest

Reserves of Mudzongwe and Ungwe, totalling 1 987 ha. Similar dry forests (9) are found in parts of Gonarezhou National Park associated with Cretaceous sandstone, and are rich in woody species with miombo species and *Guibourtia conjugata* prominent. Here elephant damage is the major threat, and most patches have been reduced to shadows of their former structure. The northern part of Gonarezhou is very diverse and warrants consideration as a possible area of international interest. At the other end of the country, in Binga close to Lake Kariba, dry forests of *Guibourtia conjugata* (10) can be found (Timberlake *et al.* 1993), and are not known from elsewhere. None are protected and many patches are now rapidly being cleared for cultivation.

In the centre of the country, where the central plateau falls away toward the southern lowlands, there are some conspicuous hills which intercept the moist air flows coming from the Indian Ocean. Although not as wet as the Eastern Highlands, the additional moisture is sufficient for forest outliers to occur which are of considerable botanical interest and contain some unusual species. The Nyoni Hills (11) south of Masvingo contain an exceptionally rich miombo woodland, several gullies of moist forest, and the only reasonably sized population of the tree *Bivinia jalbertii* in Zimbabwe, a species now greatly threatened for its good timber. Hwedza Mountain (12) south of Marondera has some small remaining forest patches, moist miombo woodland, and a few species only rarely found

Figure 5.—*Brachystegia boehmii* woodland on rocky hillside. Mazoe Botanical Reserves.

elsewhere in the country (Robertson 1991). Cutting of trees and uncontrolled grazing are destroying the woodlands, but there is a proposal for a conservation management plan through the Department of Natural Resources. Mt Buhwa (13) near Zvishavane contains an outlying population of bamboo (*Oreobambus buchwaldii*) and various other unusual species, but the two main gully forests have been destroyed by spoil tips from iron ore mining. All these hills are either on communal or private land and have little protection. Close to Harare the Mazoe Botanical Reserves (14) are possibly the best remaining examples of moist Highveld *Brachystegia* woodland on hills (Figure 5), and they also include what is probably the finest riparian forest left on the central plateau (Müller 1993). Although fully protected, the area is small (43 ha).

About 80 km^2 of rainforest occurs in Zimbabwe (less than 0.02% of the country), most of it montane (above 1 500 m) and well protected (Müller 1991). Submontane and lowland rainforest, however, has been severely reduced, and now consists mostly of relic patches. Many are on private land, but those fragments on communal land need active protection as most are on the verge of extinction.

Grasslands are another interesting group of vegetation types, often with high herbaceous biodiversity, and are associated with high altitudes (Eastern Highlands), seasonal waterlogging (Highveld, vleis), heavy soils (including pans) or mineral toxic soils (Great Dyke). However, few are directly threatened due to their lack of woody cover and the resilient nature of the grasses. Grazing may reduce biodiversity, but the major threat is from ploughing or drainage.

The main group of vegetation types in Zimbabwe is miombo woodland (dominated by *Brachystegia* species and *Julbernardia globiflora*) in its varying forms. In the Highveld virtually all the miombo on level and fertile soils has been cleared for cultivation over the last 100 years, and it is now hardly possible to find an area that does not show signs of severe disturbance. Efforts need to be made to look for good areas for conservation, particularly those with a full catenary sequence from river across flat land and deep soils to the rocky hill slopes. The situation is better with the miombo woodlands of middle altitudes (800–1 000 m), and some of these are conserved in Safari Areas.

The greatest loss of suitable witness stands of vegetation over the next 20 years is likely to occur in the communal lands or on resettlement schemes. Identification of sites suitable for conservation has been carried out for the communal lands of Binga, Gokwe, Lupane, Nkayi and Kariba districts (Timberlake *et al.* 1991). While many of these fall into the third category (local reserves), some are the only examples of unusual or rare vegetation types and fall into the second category. Identification of similar areas in other districts is a major priority.

THE FUTURE

There is still much work to be done in identifying suitable areas for plant conservation. As mentioned previously, a major task is to identify areas of good

miombo on deeper soils in the Highveld, and *Acacia* and *Combretum-Terminalia* woodlands in the drier parts of the south and southwest. The vegetation of parts of the south and southeast is also not particularly well known. Much of Matabeleland in the west of the country is covered with Kalahari sand and the distinctive *Baikiaea plurijuga* woodland (Figure 6). Suitable areas need to be identified, probably within Hwange National Park and on Forest Land. All National Parks where large herbivores prevail have to be investigated with regard to specific vegetation types which may be threatened by them, and exclosure fencing has to be considered.

Looking ahead, it is not sufficient just to identify and describe areas for conservation if we wish to keep some witness stands of the vegetation that used to cover the country. It is also imperative to ensure that plant conservation is considered in land-use planning. There are major problems in gazetting and managing such stands, particularly in the communal lands, and the responsibility, authority and technical expertise for such an exercise are not found together in any one government department. A concerted effort is required, covering Government, nongovernmental organizations and individuals, if we are to keep and manage the full range of the flora and vegetation of Zimbabwe.

Figure 6.—*Baikiaea plurijuga* woodland on Kalahari sands. Northwestern Zimbabwe.

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Human and social dimensions in the conservation of biological diversity in southern Africa

J.Z.Z. MATOWANYIKA

Social Sciences Programme, IUCN—The World Conservation Union,
Regional Office for Southern Africa, P.O. Box 745, Belgravia, Harare, Zimbabwe.

ABSTRACT

Concern for biological conservation is definitely not new. Indeed some will say this has been the core of the environmental movement for the last century and more. However, the current interest in the subject has heated up over the last few years, especially since the signing of the Convention on Biological Diversity in Nairobi in May 1992 and in Rio during June of the same year. The interest that the Convention generated in Rio as a result of the United States refusing to sign it, epitomizes the central point of this paper: biodiversity conservation is largely a human and social issue.

Indeed most of the articles of the Convention are built upon issues that are in the human political-economic and social-cultural realms. These range from concerns with national sovereignty, cooperation among countries including sharing of benefits based on biological and genetic resources and technological transfers, systems of resource management and sustainable use of resource bases, the significance of *in situ* conservation, the need for economic incentives, research and training, public awareness and such matters, and the creation of financial mechanisms for the implementation of the Convention. The document can easily be read through a human filter but does not detract from the needs of science and scientific inputs in the process.

This paper highlights the implications of these matters within the context of southern Africa and suggests approaches to promoting biological diversity conservation.

INTRODUCTION

If the number of leaders signing the Convention on Biological Diversity at the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro in June 1992 is representative of humanity, then the issue of biodiversity can be safely assumed to be of major concern to humanity. Moreover, the number of people subscribing to the debate after Rio and more interestingly, before Rio, indicates that the topic is of concern to many people. The subject itself is not new and some will go so far as to suggest that biodiversity conservation has been the chief concern of the environmental movement thus far.

Nonetheless, the experience to date has been that such conservation concerns have, unfortunately, all too often separated humanity from the integrity of

biological processes. Indeed, the major thrust in the development of protected areas was to set areas aside as examples of nature's mysteries. People were removed from these centres of biodiversity. The legacy of the endeavours of the last few decades has therefore left us with a sense that we can do something about environmental conservation but that we are separated from the environment itself. Hence, we will often believe that we can manage aspects of the environment by some form of manipulation. In manipulation, we often seek to use what we perceive as objective and impersonal processes in pursuit of the rational management of the environment. We often forget that our perception is derived from our own personal biases; this creates a selective perception of problems, or tunnel vision (Miller 1982), and is often exacerbated by our professional training.

We therefore have inherent limitations in our perception of the biophysical realm as well as in our ability to manage it. It is important to recognize these limitations and one would tend to think that it is time that such modesty was cultivated. In examining the question of whether one can manage nature, or rather manage the interaction of people and institutions with the environment, one should think the latter option is a better reflection of reality. After all, that is what took place at Rio: showmanship, brinkmanship, cajoling, threats, sweeteners and other such human relations and institutional matters, while biological processes continued to tick away.

There is an increasing awareness that closeted approaches which perceive environmental conservation and biodiversity protection as processes separate from people and society are detrimental to such conservation measures. Indeed, the Convention on Biological Diversity, signed by most countries at Rio, is a good illustration of such a recognition.

THE BIODIVERSITY CONVENTION AND HUMANITY

The preamble to the Convention (UNEP 1992), while recognizing the intrinsic value of biological diversity, goes to great lengths to emphasize the human aspects that must be considered in the promotion of biodiversity conservation. Indeed most of the articles of the Convention are built around issues that are in the human, political, economic and sociocultural realms. Such issues range from concerns with national sovereignty and cooperation among countries, including mutual sharing of benefits derived from biological resources and technological transfers, to the dependence of people and resources on sustainable use of resource bases. The importance of identification and monitoring of biodiversity is recognized as are the significance of *in* and *ex situ* conservation, the need for incentives, research and training, increased public awareness, and the assessment of the impact of development. The financial mechanisms for implementation of the Convention are also specified. The document can be easily interpreted through a human filter but this does not derogate from the needs of science and scientific inputs.

If human issues are taken to include geopolitical and economic issues, it would appear from the above that biodiversity cannot be promoted without being placed totally within human institutional arrangements. Indeed, one can say that it is quite irresponsible to do otherwise, as shown by the failures of many unsympathetic conservation programmes over the last century. We cannot and dare not fail to recognize that it is people who conceptualize the complexity of biodiversity. We have to comprehend the efforts we must put into action to promote the maintenance of biological diversity. We can act only at a human scale but we must do all we can and desist from the unsustainable development which is currently practised. Such practices have already left many species extinct, others are near extinction and almost all of the rest are under some form of immediate or foreseeable threat. The social capital that resides within our systems needs to be correctly understood and put into action to promote the process of biodiversity conservation.

Our endeavours have also left the bulk of our people in dire poverty and without much option but to continue to contribute to the impoverishment of the biodiversity that has been inflicted on the generations living in the last century. Where human endeavour has created adequate material wealth, it has been at very great cost to biological diversity, as technological and industrial processes have sought to simplify natural processes in the name of mass production and consumption. Pollution of various forms has ensued and there appears to be not much progress in stemming those processes that threaten fundamental ecosystem functioning and biotic integrity. The impacts of human misuse of the environment which have led to rapidly increasing rates of extinction are described by Myers (1993).

Many global impacts, such as those predicted through ozone depletion, the greenhouse effect and tropical deforestation, may appear to be far removed from the efforts we must make in southern Africa to promote the interests of biological diversity maintenance and rehabilitation. We would do well to examine the Convention and highlight the issues which hinge upon people, the way they organize themselves and relate to each other in the exchange of natural resources and the manner in which they relate to their environments. I see a number of important issues we must address in the region in the human realm.

HUMAN AND CULTURAL ISSUES AND BIODIVERSITY IN SOUTHERN AFRICA

A number of issues need our attention in this region, indeed in other regions of Africa as well:

1. Appreciation of the economic value of the region's biodiversity and recognition of the long-term detrimental economic impacts of phenomena such as desertification.

2. Political organizations to contribute to and gain from international and national debates on biological diversity.

3. Development of appropriate methods to foster optimal cooperation between and contribution by communities in the region.

4. Recognition and correct apportionment of responsibilities and duties to the various sectors of our societies, including, in particular, ensuring the full contribution of our urban populations.

5. Attention to issues of socioeconomic development more truthfully and thoroughly than has hitherto been the case, especially in the process of reducing poverty in the region.

There are many other factors that need to be addressed and the intention is not to be exhaustive here. A few facets of each of the statements made here are discussed below.

Economic value of biological diversity

The region needs to invest much more in understanding the economic values of various genetic materials. We have a fair understanding of the fact that the bulk of the population in the region depends on a number of plant species for food and medicinal and other purposes. However, how much do we know of the range of plant species used by various societies? Can we gauge the long-term sustainability of such uses? Do we know the rate of genetic erosion of some of the plant species? In other words, do we know how much we have mined from the biotic reserve we have had in this region and how much we have borrowed from our future needs? Can we know?

This goes for animal species as well, especially those small species which are not the stars of the international media, but are of crucial importance to people in our rural areas. What is the distribution of these species and how is their distribution being affected by activities such as crop production in the rural areas? Are there any observable trends in these distributions? Do we have a proper understanding of the dependence of our people, rural and urban, on bushmeat? Can we know, and perhaps do something about this?

Moreover, we need to get to grips with the amount of local, regional and international trade in our plant and animal species. Can we assume that this is low and are we correct in this assumption? What are the effects of this trade on the species concerned? The countries in the southern African subregion also need to be better able to negotiate with countries in the north, with full and proper information on the value of species that enter international trade. This is where such issues as the transfer of technology are important. Important in this regard, is whether the countries in this region receive the transfer of skills necessary to develop technology within the region or whether they remain dependent on imported technology.

The region has a number of initiatives built on wildlife management for both consumptive and nonconsumptive use. These include such projects as

CAMPFIRE in Zimbabwe and ADMADE in Zambia. Many other countries are considering introducing such efforts. The problem with these projects is that they concentrate on selected species. Could these projects be expanded so that other less spectacular but locally valued species are also conserved in localized areas? The valuation of the diversity available for immediate benefit to the local people must be correctly assessed and encouraged. We must also recognize that we, as experts of one hue or another, will not have the resources to fully know what exists in the local situation and cannot hope to do so in the very long-term future. We therefore have to learn that local communities, given the correct incentives, have the best knowledge of what exists in their areas as a result of their dependence on these resources. The aggregate effect of this knowledge is likely to be beneficial to biodiversity conservation as a whole.

There are many facets of economic value of species that must be understood. As well as protecting the species that are utilized in various communities, the protection of biodiversity needs to be seen to be of value in itself. Awareness of the value of biodiversity at various levels of societal organization is essential and this calls for political organization.

Political action and biodiversity in the region

Besides issues of peace and stability in countries like Mozambique, Angola and South Africa, where war and political violence have wreaked havoc on local ecosystems and many species, general political issues must be addressed. At a regional level, the Southern Africa Development Community (SADC) countries need to be counted upon to coordinate their inputs into processes such as the Convention on Biological Diversity, in addition to giving political support to regional strategies. At national levels, ratification of the Convention is essential. Moreover, national strategies for promoting biodiversity are essential. At a policy making level, states must also mobilize resources from within their borders and beyond and allocate adequate funds for biodiversity conservation.

On the ground, it is essential that correct mobilization of those who use biological resources occurs, giving these actors in the biodiversity scenario proper means of control of resources. Appropriate institutions, including indigenous ones, need to be strengthened. Because of the nature of state politics and organizations in the region, such issues must necessarily depend on national governments for their success. Without these, and local goodwill, cooperative action is likely to be difficult.

Nurturing support of local populations

Local communities in all sectors of society must be extensively involved in ensuring that biodiversity is conserved. This stands to reason in rural areas, where the people live with the species we seek to conserve, whether they are of direct resource value to them or not. Rural communities impact directly on the ecosystems which, in the interests of biodiversity conservation, we need properly

conserved and managed. They suffer or benefit from the existence or extinction of the specific animal and plant species we seek to protect. We cannot hope to appropriate the responsibility to protect these species and ecosystems without the full support and cooperation of the local communities. It is essential to find ways of enlisting their full and willing involvement in biodiversity conservation.

Hence, the employment of indigenous forms of thought and action become important. For example, how do people collect information about species in their areas? How is such information recorded within the community and passed on to others outside the communities? Is this information not useful to us as we grapple with the process of collecting data and assessing the levels of diversity of species and ecosystems? If we pay attention to the modes of local organization for responding to local environmental challenges, we may find that we will create positive bridges for discussion with local peoples. This is an important issue for both *in* and *ex situ* conservation. There are many other aspects to this equation, some of which have been referred to above. Participants in a workshop such as this perceive our tools of analysis and of enquiry to be exclusive to us as natural and physical scientists. We often treat local people as objects of research rather than partners. Such perspectives create disharmony. Often we apportion blame and responsibilities incorrectly. Biodiversity conservation can be better promoted by proper synergy in local environments.

Apportioning responsibilities in the appropriate manner

The point just made leads to the process of apportioning responsibility. One issue stands out as particularly important: there is a very high expectation that the conservation of species, both plant and animal, lies outside urban areas. Indeed, the same assumption holds in the apportionment of responsibilities to species-rich countries of the south and species-poor but industrially and economically rich northern countries. Apportionment of duties and responsibilities based on this assumption cannot foster the long-term viability of our approaches in biodiversity conservation. This is an issue of both geopolitical significance and local consequence.

As we work out national approaches and strategies for biodiversity, it behoves us to look critically at who contributes what to the current erosion of diversity. Is it fair for us, for example, to exclude urban workers who buy food and medicinal plants from the rural areas from contributing to the conservation of plant species? How can the true cost of such species and their loss be more properly apportioned? What remedial actions must the urban dwellers implement to redress the losses of diversity resulting from their consumption? We need to address these issues and ensure that urban dwellers make an appropriate contribution. An illustration is the need for urban dwellers to contribute to the research on and propagation of indigenous plant material. Another example is the need for urban dwellers to be a major target for any public awareness of the issues of biodiversity. After all, they are in a better position to gain access to the kinds of media used in propagating information.

Moreover, urbanization is a growing phenomenon in the region. Countries like Zambia have close to 50% of their population in urban areas. Others have smaller proportions of urban dwellers, but the trend to increased urbanization is evident. This has contributed to increased poverty, through impoverishment of the material resources needed by people and impoverishment of biological diversity. All this needs to be examined against the background of the thrust of the development process to date.

Development thrusts and biodiversity

Southern Africa, like most other developing regions, has depended extensively on the mining of primary resources. The biotic realm has suffered much, especially in those areas linked to agricultural production. There is a steady loss of local seed varieties as hybrids are developed and promoted as the solution to food production by our extension services. There is also a steady loss of information on such land races and other locally utilized species. This information fails to be transmitted intergenerationally and also does not effectively enter into the scientific realm. There are some moves to rectify this but there do not appear to be adequate policy measures in place to promote the preservation and conservation of indigenous seed.

Such a paucity of policy instruments and on-the-ground activity has often led to direct poverty of the people. The recent drought in the region serves as a telling illustration. It is becoming evident that the region needs a better seed bank to help cushion the worst impact of climatic factors. In view of the present climatic changes, one wonders which species can be utilized to mitigate the negative impacts of such change. The impacts of climatic change are likely to be worst for rural peoples. This is only one factor impacting on the poverty of the people. There are many others that must be investigated, such as national development planning, the dependence upon primary biotic resources for balance of payments in a world economy which is less than willing to pay the proper price for these, the overcentralization of policy and the marginalization of people.

It is appropriate to caution that, if we need to strike the correct balance between countries in the southern African subregion and the south in general, we must equally strive to strike a balance within our countries. The task is large and we can ignore it only to the detriment of the well-being of the natural resource base upon which we depend.

A CONCLUDING NOTE

The above matters and many others are all germane to biodiversity. These examples illustrate how biodiversity matters are very much encased in processes that are handled in the human realm. This may involve national and regional politics. An example is the slow progress made by southern African countries in ratifying the Convention on Biological Diversity. At a local level it may also involve mobilizing local people in promoting proper biodiversity management. It may also

be linked to the choices we need to make in apportioning resources, duties and benefits. All these factors play, perhaps, the most significant role in promoting the interests of biodiversity conservation. If a country fails to recognize the crucial roles played by its museums and botanical gardens in collecting and storing data on its biota, surely this has to be seen as a problem emanating not from the scientific community who strive to collect such data, but from the process of setting priorities within the national sphere. Such a process may, very often, apportion much of the national resources to a military arsenal or a luxurious infrastructure. Politics therefore plays a vital role, as was evident at Rio. We have to assist in sharpening the way ahead—by making the correct human choices.

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Combining skills: participatory approaches in biodiversity conservation

A.B. CUNNINGHAM

WWF/UNESCO/KEW People and Plants Initiative, 84 Watkins Street, White Gum Valley, 6162, Western Australia.

ABSTRACT

Drawing on examples from Africa, Australia and the Americas, this paper emphasizes the value of a 'cross-pollination' of ideas between resource users, researchers and resource managers in conserving customary knowledge and botanical diversity. Knowledgeable rural people, who have learnt through resource use and acute observation rather than through formal training, can be an invaluable source of information for plant conservation purposes. In this context, people from rural communities surrounding protected areas can play decisive roles in species inventory, planning, research and monitoring for conservation purposes. What is urgently required before much of the accumulated customary knowledge of ecosystem functioning and species uses disappears, is the development of formal and field-based training to develop cross-cultural communication skills for participatory research.

INTRODUCTION

Ironically, though conservation is a human activity for the benefit of people, in landscapes usually changed or used by people, the people-conservation interface has been neglected until recently by many conservation biologists, planners and national park managers. One of the reasons for this has been a mistaken perception that both biological and cultural systems are static and unchanging. Conservation areas have demarcated 'pristine' land or 'wilderness' for conservation purposes with limited recognition of the dynamic nature of biological systems and the role that disturbance (including human influence) has had in creating or maintaining habitat and species diversity. Ethnobotanical work has an important role to play in rural development and plant conservation and there has been a resurgence of interest in this field with emphasis on the people-conservation interface and on screening programmes for new natural products development. Ethnobotany is also a research field which has developed rapidly in southern Africa from an inventory phase of plant uses to a quantitative one focused on economic, nutritional and resource values of plants to people. It is now proceeding to a stage where conservation biology, economics and social science skills are becoming closely linked.

This paper focuses on three main issues. First, the importance of taking the culture-nature interface into account for effective maintenance of biological diversity, in addition to maintaining cultural practices and resource values associated with wild plant use. Second, the value of traditional ecological knowledge (TEK) at all levels of the planning process, whether inventory, key factor analysis, research, resource use or monitoring. Third, the recent developments in ethnobotanical research which blend quantitative botanical approaches with social sciences skills. In each case, this represents a move beyond limited consultation towards participatory, community-based research. If implemented, this can result in a partnership linking the skills and knowledge of the indigenous and local peoples with those of formally trained biologists and social scientists leading to more effective management of a bioregion of global importance.

CHANGING PRIORITIES AND APPROACHES IN ETHNOBOTANICAL RESEARCH

Ten years ago, when Liengme (1983a) reviewed ethnobotanical research in southern Africa, the major focus had been on recording vernacular names and uses of wild plant species. Good examples are the work by Catholic missionaries (Bryant 1909; Gerstner 1938, 1939, 1941) and colonial botanists (Medley Wood & Evans 1898). Quantitative studies initially focused on chemical analyses of medicinal and toxic plants, documented in the outstanding work by Watt & Breyer-Brandwijk (1962), or nutritional analysis of bush foods (Wehmeyer 1966; Van der Merwe *et al.* 1967). Few studies combined quantitative research with insights from both the biological and social sciences. A notable exception was Quin's (1959) seminal study quantifying diet and the nutritional importance of bush foods to rural people in the northern Transvaal.

At the time of Liengme's (1983a) review, quantitative ethnobotanical studies in southern Africa were limited mainly to measurement of wood use for fuel and building purposes (Best 1979; Gandar 1983; Liengme 1983b; Whitlow 1979), concurrent with international interest in fuelwood as the major energy source in developing countries (Openshaw 1978). With the exception of Moll's (1972) quantitative study of *Hyphaene coriacea* densities and speculation on palm wine and leaf production, less attention was paid to quantitative work on market surveys or the effects of harvesting nontimber products, despite innovative work on palm wine tapping (Tuley 1965) and chewing sticks (Adu-Tutu *et al.* 1979) in West Africa. Quantitative approaches in ethnobotany have recently been reviewed by Phillips & Gentry (1993b), concentrating on work done in the Americas and Asia. In southern Africa, quantitative work has been done on the ecological effects of traditional indigenous tree conservation (Campbell 1986), marketing, economics and impact of palm sap tapping (Cunningham 1990a, b), crafts (Cunningham 1988b; Cunningham & Milton 1987), traditional medicines (Cunningham 1991), *Phragmites australis* reeds (Cunningham 1985) and *Cymbopogon* thatching grass (Shackleton 1990).

Increasing human pressure on habitats with high conservation value has stimulated several studies quantifying the economic value of sustainably har-

vested forest products in Peru (Peters *et al.* 1989), Malaysia (Saw *et al.* 1991) and Belize (Balick & Mendelsohn 1991), comparing these to alternative land uses such as pulpwood plantations or cattle-ranching. What was not taken into account in the costing exercises by Peters *et al.* (1989) or Balick & Mendelsohn (1991), was the cost of managed use. This important feature is taken into account by Muir (1991) in his research on the effects of pole cutting on Afromontane forest in South Africa, showing that it was more cost-effective to cultivate an alternative source of poles outside the forest than to sustainably manage pole cutting within the forest. In addition, Muir (1991) also used computer-based modelling as a tool to predict how different levels of pole cutting would affect the future forest canopy.

More recently, since 1990, 'participatory rural appraisal' methods developed through social sciences skills are being blended with natural sciences work, linking local knowledge and formal academic approaches in resource management. This has been most effectively developed in India (Poffenberger *et al.* 1992) and needs to be complemented by applied ecological work and predictive modelling. This aspect of the people and plant conservation interface is discussed in more detail in this paper.

TRADITIONAL ECOLOGICAL KNOWLEDGE AND CONSERVATION PLANNING

To view conservation areas or natural resources through the eyes of resource users is an instructive and important process for any conservation biologist or national park manager. To do so means viewing biodiversity at any level from a very different perspective, working at an interface between disciplines—or what are becoming 'new' disciplines of human ecology, ethnobotany or ethnoecology (Toledo 1992). It also requires a linkage between folk classification systems for different levels, whether landscape units or plant species, which in turn affirms the historical links between people and landscapes described by Toledo (1988) for Mexico, but could as well apply in southern Africa:

'*In a country that is characterised by the cultural diversity of its rural inhabitants, it is difficult to design a conservation policy without taking into account the cultural dimension; the profound relationship that has existed since time immemorial between* nature *and* culture... *Each species of plant, group of animals, type of soil and landscape nearly always has a corresponding linguistic expression, a category of knowledge, a practical use, a religious meaning, a role in ritual, an individual or collective vitality. To safeguard the natural heritage of the country without safeguarding the cultures which have given it the feeling is to reduce Nature to something beyond recognition: static, distant, nearly dead.*'

Amongst formally trained researchers or planners, views of landscape are often biased by orientation towards one academic discipline or another. Applied ecologists, for example, are primarily concerned with biological factors, whilst anthropologists or social scientists have insight into cultural and socioeconomic factors. In rural communities in Africa local resource users also see landscapes or the resources within them in different ways depending on experience, gender

or specialist resource use (herbalist, honey-hunter, master fisherman, midwife). To different people within the same rural community vegetation may appear to be series of overlapping, linked resource patches of bush foods, medicinal plants, thatch of varying heights and qualities, plants of varying symbolic power, or habitat for different mammals or reptiles. This 'patchiness' is both above and below ground as well as varying in time. To African traditional healers, for example, as Turner (1967) pointed out in his classic book on cognitive anthropology in Zambia, a forest would be a 'forest of symbols'. To a hunter or woodcutter, the same forest might be viewed very differently (Figure 1).

The interest, perceptions and values placed on the managed area by people living in or around the area concerned have an important influence in effective planning and management systems. Effective management of natural resources used by people similarly depends as much on an understanding of the biological component as it does on the social, religious and economic aspects of natural resource use. The question is how can we link traditional ecological knowledge and formal scientific knowledge to provide effective planning and management in order to unravel some of this complexity?

A general guideline in any planning process for biodiversity conservation is to take a hierarchical approach (Noss 1990), proceeding from the top downwards

Figure 1.—'Pristine' *Terminalia sericea–Sclerocarya birrea* savanna or site of the ancestral homestead or a woodland of symbols? Taking different cultural perceptions of vegetation and their uses into account can generate new questions and hypotheses on vegetation dynamics, plant conservation, land-use conflicts and resource management.

from a broad ('coarse-grained') inventory, to a more focused ('fine-grained') approach, generally working through four levels: (i) a regional landscape level, (ii) a community ecosystem level, (iii) a species-population level, and (iv) a genetic level within species.

Regional landscape level

Use of GIS computer-based mapping systems and programmes such as ARCINFO has become standard practice. There is no doubt that these are useful tools in the planning process, including the mapping of areas of high biological diversity or environmental sensitivity. What could also take place is to incorporate 'alternative' views of species diversity and patterns of resource distribution based on views of rural herbalists, wood cutters or women gathering bush foods. 'Ground mapping' techniques are one way of incorporating local insights on species and distribution and patchiness within plant communities. Participatory approaches to mapping have been successfully developed with rural communities in India (Poffenberger *et al.* 1992). 'Ground mapping' techniques could similarly be used in southern Africa to illustrate resource distribution, favoured sites for beekeeping, (Figure 2) edible fruit-bearing species, particular medicinal plants or soil mapping.

A key to the participatory mapping process used by Poffenberger *et al.* (1992), is the production of sketch maps which illustrate the spatial distribution of resources, of resource flows or of landscape features of significance. As Poffenberger *et al.* (1992) point out with specific reference to forest resources, it is an approach which is relevant to mapping geological features, soil or vegetation types:

'*Through interactive exercises with the community and observation, the research team can help to create a picture of spatial resource use patterns by developing sketch maps, produce flow maps and transects of resource use patterns. The main purpose of diagnostic sketch-mapping is to create a visual representation of the resource system which can easily be understood by both villagers and foresters.*'

In any community, it cannot be overemphasized that mapping can only take place on the basis of an established position of trust between researchers and research participants. This requirement makes any community-based work exceptionally difficult and sometimes impossible in parts of southern Africa experiencing political and military conflict. If successfully established, however, these processes provide a means of establishing common ground and for joint planning. This enables the identification of areas of the regional landscape with outstanding biological and cultural significance—not from the perspective of formally trained planners, but from the perspective of the members of the local community themselves.

A recent example of this linkage is the interaction between scientists and people of the Western Desert (Anangu) community in conservation in Uluru (Ayers Rock-Mt. Olga) National Park in central Australia in identifying units (Table 1) and biological inventories.

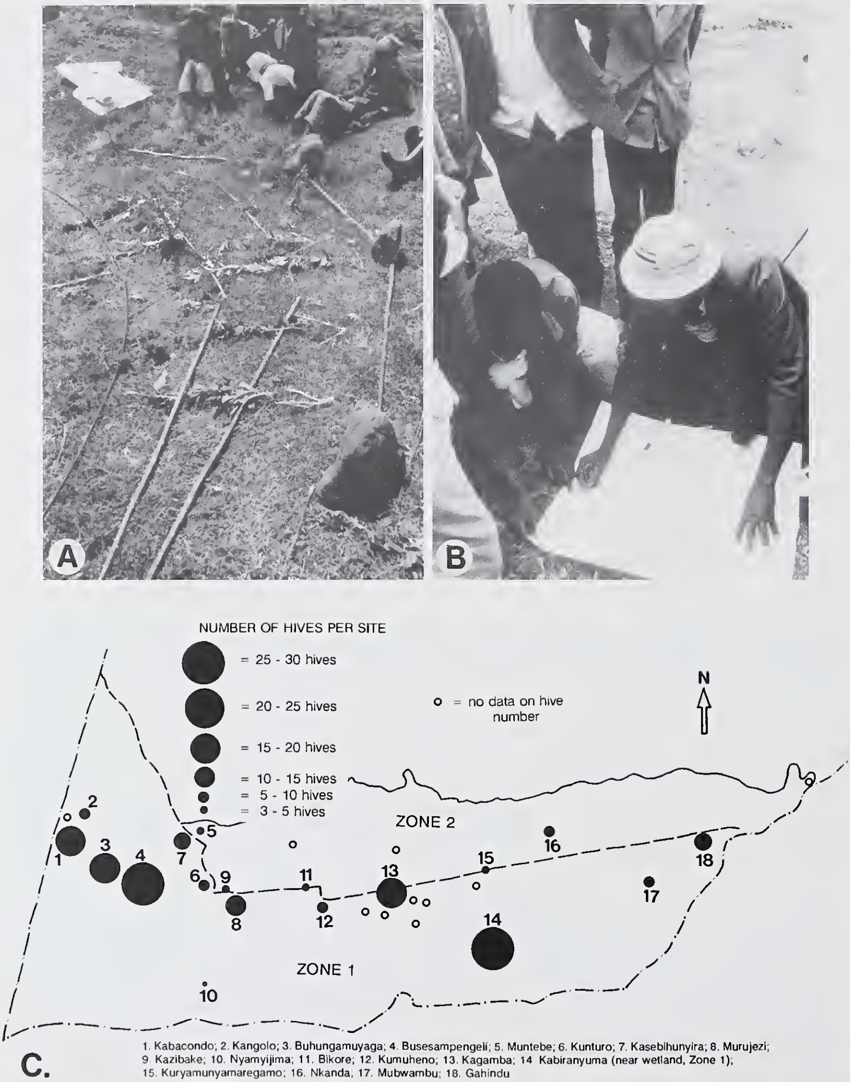

Figure 2.—Linking with local knowledge at a landscape level. A. Ground mapping by beekeepers from Chana village, southwestern Uganda, mapping out Mgahinga Gorilla National Park showing the three Virunga volcanoes, mountain streams and flower inflorescences to mark the main sites used for beekeeping prior to the exclusion of beekeepers from the National Park in 1992. Bamboos mark altitudinal zones within the Park. B. Botanist Alfred Tsekeli facilitating transcription of the map by a beekeeper, followed by writing in local names for hills and numbers of hives and beekeepers associated with each hill. C. Summary of information from beekeepers with names of hills. Beekeepers had an excellent knowledge of vegetation composition at each site which could be followed up in formal vegetation surveys.

TABLE 1.—Major landscape classifications identified by Anangu people compared to scientific classifications of the landscape (from Baker & Mutitjulu Community 1992)

Traditional ecological knowledge	Scientific knowledge
Puli Puti (woodland) Pila (spinifex sandplain) Tali (sand dune, dune systems Wanari (mulga shrubland) Ulpuru (red kangaroo habitat) Karu (creeks and associated banks) Tjintjira (clay pans)	Monoliths Fans and alluvium Transitional spinifex sandplain Spinifex landscapes Extensive mulga tracts Malee tracts

A key issue for planners may be to match the relatively fine-grained level of resolution of local community perspectives at a fine-grained scale (which may be transferred to a 1:5 000 or 1:10 000 scale map) to the regional landscape scale at 1:50 000 or at an even larger scale. This again requires a hierarchical approach to 'filter' information according to various levels, from the 'coarse-grain' levels of regional landscapes and ecosystems to the 'fine-grain' levels of vegetation, habitat structure and species distributions, both spatially or seasonally.

Community/ecosystem level

The approach described above can also be applied at community and ecosystem level, interfacing with scientific mapping of vegetation or habitat. At a finer level of resolution, fieldwork within habitats facilitates a better understanding of ecosystem dynamics amongst conservation biologists. This is particularly relevant in forest ecosystems, which are extremely complex in terms of life-form and species diversity, where generation times of some plants are long and understanding of patch dynamics is limited.

Scientific techniques such as palynology give a far greater knowledge of shifting vegetation patterns with time, including vegetation change due to human disturbance. Examples are Taylor's (1990) work in East Africa or Kershaw & Sluiter's (1982) studies in northeastern Queensland. These studies provide a valuable perspective on long-term vegetation dynamics that cannot be matched by traditional ecological knowledge. On a shorter time-scale, however, traditional ecological knowledge can provide valuable insights into ecosystem functioning. Keen observation by forest peoples in Africa, Asia, Australia or South America has led to a rich source of knowledge on forest structure, canopy gap dynamics, pollination or dispersal of forest plants. A good example of this is the Kayapo Amerindian terminology for different forest types (Table 2).

TABLE 2.—Zones within forest recognized by Kayapo Amerindian people, Brazil (Anderson & Posey 1989; Hecht & Posey 1989)

Kayapo terminology	Botanical equivalent
Ba-epti	Liana forest
Ba-rarara	Forest in which light penetrates to the canopy floor
Ba-kam	Gallery or riverine forest
Ba-kre-ti	Forest opening
Ba-kot	Forest transition zone
Kapot	Savanna or scrub savanna
Ba-tyk	High, dark forest
Ba-kumrenx	Forest with large trees and a herbaceous understorey

Also important is the role of traditional ecological knowledge at the ecosystem and habitat level in:

- faunal habitat associations such as reptile use of habitat in Uluru National Park (Baker & Mutitjulu Community 1992); similar work has been done in marine systems in Oceania (Johannes 1981);
- major dispersal agents of plants and identification of 'keystone' species and identification of mass-fruiting species;
- soil classification systems with Kayapo Amerindian people, Brazil (Hecht & Posey 1989), and in soil mapping in Zambia (Trapnell 1953);
- plant-pollinator associations and information on flowering strategies of synchronous, periodically flowering Acanthaceae (Table 3; Cunningham 1992a);
- oral historical evidence and field knowledge of the arrival and effect of exotic plants, such as *Tagetes minuta*, reported by local people to have been purposely brought into southwestern Uganda from Zaïre so that it could be planted and the leaves used to deter ants from entering their homes (unpublished field notes, 1993);
- temporal knowledge of flowering and fruiting patterns, feeding of birds and mammals or life cycles of honey-producing bees or edible Saturniid moth larvae (Campbell 1986; Cunningham 1985, 1992a);
- the formation of cultural landscapes through fruit dispersal and protection in camp sites, in agricultural fields (through conservation of edible fruit-bearing trees such as *Sclerocarya birrea*) or through the use of fire (Cunningham 1988a).

Joint research on stingless bees also provides a good example of detailed participatory research in which knowledgeable indigenous people can play a valuable role. Not only would this provide 'new' scientific knowledge of tropical forest plant-pollinator interactions but it would also provide useful information on

TABLE 3.—Records of forest plants favoured by bees as a source of nectar, wild hives or by Meliponid bees as a source of resin for nest construction. Exotic species are marked (*) (from Cunningham 1992a)

Plant species	Family name	Bakiga name	Life form	Use
Alangium chinense	Alangiaceae	omukofe	tree	heart rot, wild hives
Albizia gummifera	Fabaceae	omushebeya	tree	nectar source
Beilschmidia ugandensis	Lauraceae	omuchoyo	tree	heart rot, wild hives
Bosqueia phoberos	Moraceae	omukumbwe	shrub	nectar source
Brilliantasia nitens	Acanthaceae	omulihashenje	shrub	major nectar source when mass flowering occurs
Brilliantasia sp.	Acanthaceae	omuhero	shrub	major nectar source when mass flowering occurs
Drypetes gerrardii	Euphorbiaceae	omushabarara	tree	nectar source
Carapa grandiflora	Meliaceae	omuruguya	tree	heart rot, wild hives
*Cupressus lusitanica**	Cupressaceae	—	tree	resin collected by Meliponid bees for hive construction
Faurea saligna	Proteaceae	omulengere	tree	very important nectar source
Hallea rubrostipulata	Rubiaceae	ngomera	tree	nectar source
Harugana madagascariensis	Clusiaceae	omungolero	tree	sap collected by Meliponid bees for hive construction
Macaranga kilimandscharica	Euphorbiaceae	omurara	tree	nectar source
Mimulopsis solmsii	Acanthaceae	ekiwisi	shrub	nectar source
Maesopsis eminii	Rhamnaceae	omuguruka	tree	nectar source
Prunus africana	Rosaceae	omumba	tree	heart rot, wild hives
Rawsonia spinidens	Flacourtiaceae	omusalya	shrub	nectar source
Seriostachys scandens	Acanthaceae	omuna	climber	major nectar source, mass flowering every 4–8 years
Strombosia scheffleri	Olacaceae	omuhika	tree	heart rot, wild hives
Symphonia globulifera	Clusiaceae	omusisi	tree	sap gathered by Meliponid bees for hive construction
Syzygium guineense	Myrtaceae	omugote	tree	heart rot, wild hives, nectar

management of bees producing a nutritionally, economically and culturally important resource.

Case example: pollination ecology and traditional knowledge

Knowledge of plant-pollinator interactions and reproductive biology of forest plants is an essential component of responsible forest management (Bawa & Krugmann 1991), yet very little is known of plant-pollinator interactions in tropical forests, where there are a wide range of pollinators. Even in neotropical forests where plant-pollinator studies have proceeded over 20 years, such as the work by Frankie *et al.* (1990) in Costa Rica, there are many unanswered questions.

Pollination biology of individual species is highly relevant to forest management, yet information on this subject is limited mainly to anecdotal evidence. This applies even more to plant-pollinator interactions at a forest community level. In Costa Rica, Frankie *et al.* (1990) have shown that moths and bees are the most important pollinators, and after 20 years of study, they are concentrating their research on the nesting biology, chemical ecology, habitat preferences and population ecology of stingless bees (the anthropid bee genus *Centris*).

Although the importance of bees as forest plant pollinators relative to other insects, birds or mammals is poorly known, there is no doubt that they play a significant role as pollinators. Stingless bees (Meliponinae: Apidae) are also a source of honey and traditional medicine in a number of rural communities across southern Africa (Namibia, Botswana, South Africa, Mozambique). Adequate forest management strategies must not only take into account the way in which pollinator populations are influenced by changes in plant species composition, but also how pollinator populations are affected by fuelwood use or fire. Frankie *et al.* (1990), for example, have shown that forest fires, destruction of deadwood nest sites and population levels of oil-producing flowers of a climber in the Malpighiaceae are critical to *Centris* bee pollinator populations. Similar factors may also apply in Africa, with important implications for human uses such as firewood collection or burning practices. Direct involvement of knowledgeable honey-hunters as research participants directing research methodology on forest bee pollinators, coupled to detailed pollen analysis can provide information on forest plant-pollinator interactions and could be more cost- and time-effective than other approaches. A good example is the detailed knowledge that Batwa pygmy honey-hunters in southwestern Uganda have of bees, including six stingless bee (*Trigona* and *Meliponula*) species (Cunningham 1992a; Table 3), which is now being coupled to pollen analysis in joint work between honey-hunters and local biologists.

Species population level

Compilation of inventories of plant and animal species is an important step in surveys to identify unique components within protected area systems, yet even in South Africa, Siegfried (1989) found that comprehensive lists of all five taxa (plants, reptiles, amphibians, birds, mammals) were available for only 28 of 582 nature reserves. For this reason, Siegfried (1989) suggested that complete lists of species and particularly of plants should be compiled as a matter of urgency. In most planning exercises inventories are done on the basis of Linnaean taxonomies. This is a perfectly valid approach, but it is extremely useful to call on the skills of knowledgeable local people on the basis of folk taxonomies to assist in these surveys, particularly when skilled biologists and taxonomists are a scarce resource (Figure 3).

Folk taxonomic knowledge can be invaluable in inventory work for conservation purposes, whether for botanical or faunal surveys. Baker & Mutitjulu Community (1992) point out from their studies in Uluru National Park, central Australia:

'In a number of instances Anangu provided names of animals which did not match any that were caught at the survey sites. One such animal was tjakura. *Anangu provided a detailed description of this reptile and brought the animal to the scientists who identified it as the great desert skink (*Egernia kintorei*). This species was not caught on any of the survey sites, and was found to be restricted to a particular locality within the Park. The woma python (*Aspidites ramsai*) and Stimson's python (*Bothrochilus stimsoni*) were also recorded for the survey only by Anangu.'*

There is no doubt that such traditional knowledge and folk taxonomy can be equally invaluable in floral or faunal surveys. Insights from both Linnaean taxonomy and cognitive anthropology are important, however, to ensure that cross-cultural confusion does not occur. Several species within a genus may have

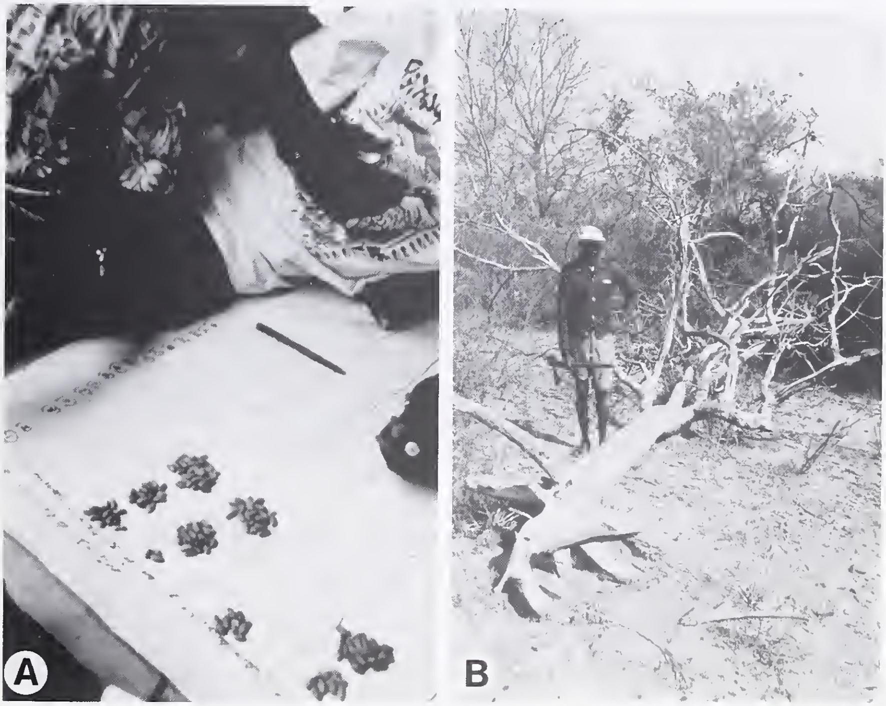

Figure 3.—Linking with local knowledge at a species level. A. Children from Etsha village, Botswana, listing then ranking which edible wild fruits are most favoured and why in a matrix using different numbers of beans to rank different qualities. The same approach can be applied to quantify scarcity or favourability of plant resources from a local perspective. B. Local craftworker Julius Rivero next to a bird plum or *motsentsila* (*Berchemia discolor*) tree in traditional dye resource harvesting site identified from discussions and interviews with craftworkers at Etsha in 1982. The demise of all trees in this population has been monitored since then (1993).

the same vernacular name, names may vary regionally within the same language group or alternatively, a single species may have many names, such as the eight Zulu names for a single medicinal plant species [*Curtisia dentata* (Cornaceae)] (Cunningham 1991). Folk biological classification systems may also have totemic links. In Groote Eylandt, Australia, for example, an Anindilyakwa speaker seeing a red-winged parrot (wurruweba, *Aprosmictus erythropterus*) flying overhead may say, there goes my brother-in-law (Waddy 1982), which is sure to confuse a biologist unaware of the totemic connection of the species!

Genetic level

Recent advances in conservation biology have increased awareness of conservation of genetically viable species populations. There is also a widespread awareness of the selective processes that peasant farmers in Africa, Asia and the Americas have had on development and maintenance of land races and crop plants (Fowler & Mooney 1990). New techniques for isoenzyme analysis and DNA-fingerprinting offer the opportunity for testing the insights of local resource users. Examples I have recently respectively encountered in fieldwork in Botswana and Uganda are:

- recognition of differences in *Hyphaene petersiana* palm leaf quality (pliability, colour, shape of unopened leaf apex, number of spines) in addition to leaf length that may be due to genetic differences in addition to environmental factors (Cunningham 1992b; Table 4; Figure 4);
- patchy distribution of *Arundinaria alpina* bamboo and variation in height, diameter, internode length and flexibility in maintained bamboo forest, Uganda, recognized by bamboo cutters. The qualities of height and flexibility were considered to be maintained when rootstock was planted at homesteads, suggesting that these differences may be due to genetic factors in addition to soil moisture and depth (unpublished field records, 1993).

TABLE 4.—Reasons given by basketmakers why unopened leaves of *Hyphaene petersiana* palms cultivated as an alternative supply source were rejected or considered acceptable for basketry (from Cunningham 1992b)

Reasons given	Etsha-5 % (number)	Etsha-8 % (number)	Reasons given	Etsha-5 % (number)	Etsha-8 % (number)
(a) Good qualities			(b) Poor qualities		
'Soft' (pliable)	43.4% (26)	30.1% (21)	'Too hard'	33.3% (20)	51.4% (36)
'Not rough' (good texture, fewer spines)	6.7% (4)	5.7% (4)	'Too thick' 'Too short'	8.3% (5) 23.3% (14)	0 12.8% (9)
Sharp tip	0	1.4% (1)	Yellow colour Leaf apex skew	1.7% (1) 0	2.9% (2) 1.4% (1)

Figure 4.—Craftworkers rating different qualities of *Hyphaene petersiana* leaves for basketry in a pilot-study cultivation site (1992).

RESOURCE USERS AND RESOURCE MANAGEMENT

Although individuals with the richest traditional knowledge often live in remote areas and are most marginalized by urban-based (and biased) policy makers, their skills are well known within their own communities. As Nabhan *et al.* (1991) point out, however: '*More often than not, conservation biologists are unaware that indigenous people have detailed knowledge of a particular rare plant or animal that is under study. Even when not biased against traditional peoples, these biologists often lack the skill of ethnographic interviewing and the incentives to learn from indigenous people who live in close proximity to rare species. To date only one US endangered species recovery plan, which recommended local Navaho participation in the habitat protection and plant population recovery efforts for* Carex specuicola *has included ethnobotanical data derived from indigenous people.*'

Similarly, social scientists with training in cross-cultural communication lack the taxonomic skills or ecological insight of conservation biologists. For this reason, a team approach involving local traditional experts, biologists and social scientists can be very useful.

CUSTOMARY RESTRICTIONS: GUIDES FOR CONTROLLED HARVESTING

Customary restrictions and tenure systems facilitating control over resource harvesting have been well documented in marine (Johannes 1981; Johannes & MacFarlane 1992) and freshwater systems (Scudder & Conelly 1985), but are less well documented in the terrestrial environment. Cultural change, commercial interests and an influx of outsiders, all weaken customary conservation practices. Nevertheless, traditional conservation practices and customary tenure over hunting, gathering or fishing areas provide a useful guide to culturally acceptable restrictions to prevent resource overexploitation.

Customary resource management practices can also play an important role outside of core conservation areas. Enforcement of customary regulations in traditional societies is often achieved through mobilization of religious beliefs, customary ecological knowledge and internal politics within communities. In Africa, and possibly elsewhere, a Eurocentric bias to conservation thinking has undercut the role that traditional political structures historically played in resource management. Tribal ‘policemen’ were replaced with uniformed game guards, headmen by conservation officers and tribal courts and customary law by the governmental legal process. Despite this, encouraging examples do exist. In Namibia, for example, rhino and elephant poaching is prevented by local people (‘auxiliary game guards’) appointed by and under the authority of local political leaders (Owen-Smith 1986).

The knowledge and perceptions of resource users can also provide valuable insight into the scarcity of plant resources, for example in developing a conservation policy on medicinal plants in southern Africa (Cunningham 1991) or plant conservation in arid North America (Nabhan *et al.* 1991). First, such knowledge is particularly useful as it has been gathered over many years of harvesting, processing or trading these resources, and often has a species-specific use. Second, the validity of these observations from a scientific viewpoint can be gauged against current scientific knowledge of geographical distribution, rarity and extent of exploitation of species from field observation, herbarium/museum records or from the literature. It therefore represents a practical method suited to inventory surveys of shorter duration in complex habitats with a high species diversity which can then identify key ‘indicator’ species for damage assessment, monitoring or cultivated alternatives. In some cases, as in joint research on medicinal plant conservation, the knowledge of resource users can also be embarrassingly more accurate than data on geographical distribution obtained from published records and herbaria (Cunningham 1991).

DISCUSSION

Some of these issues may seem remote at a conference in academic urban surroundings on the slopes of Table Mountain at the southern tip of Africa. Two examples illustrate why this is not the case. First, the southernmost Afromontane forest patches on the mountain behind the conference centre are undoubtedly threatened by destructive harvesting of *Curtisia dentata* and *Rapanea melanophloeos* tree bark in response to a commercial, species-specific demand for traditional medicinal purposes. This demand is growing monthly in response to swelling numbers of traditional medicine users arriving to live in shacklands on the Cape Flats. Second, the Cape region was the ancestral home of the /Xam hunter-gatherer people, who undoubtedly had a deep knowledge of ecological issues and an intense symbolic and religious attachment to this landscape (Figure 5). By the beginning of this century, the /Xam people, their spoken language and most of their knowledge had gone. What was saved, is a tribute to a few individuals. Starting in the 1870s, Wilhelm Bleek and his sister-in-law Lucy Lloyd worked with /Xam people who were serving prison sentences at Breakwater Convict Station in Cape Town. The result was nearly 13 000 pages of interviews and a permanent record of the /Xam language.

Figure 5.—Just as William Bleek's invaluable notes of /Xam-San belief systems and language are a fraction of their knowledge of vegetation dynamics, diversity and uses, so the paintings of San peoples of the Natal Drakensberg reflect a deep religious, ecological and utilitarian knowledge of plants that has also disappeared in less than a century.

Cultural and biological change, interlinked through plant uses, is proceeding at a more rapid pace than ever before. Support and training for ethnobotanical work are required to conserve both species and disappearing customary knowledge. Implementation requires a conscious change of approach, however, as Nabhan *et al.* (1991) point out with specific reference to plant conservation:

'*Regardless of the* potential *for building on indigenous people's plant traditions to further the conservation of rare species, certain ethnocentric attitudes remain among Western-trained conservation biologists which keep this potential from being fully realised. Because many biologists are intent on analysing so-called natural systems, they often ignore that they are really observing relationships between organisms and environments that have been influenced by humankind over thousands of years..... Even when they do not ignore human influences, such 'natural systems' biologists typically treat human presence as a purely negative phenomenon, a nuisance or intrusion.*'

Increasingly over the past decade researchers working at the interface between biological and social systems have broken away from this mindset, producing innovative work of value to local peoples, resource management and to the academic world. Joint research, planning, monitoring and management have a major role to play in achieving the goals of maintaining biological and cultural diversity worldwide. Truly participatory research requires time, but it can also save time and research funding through valuable new insights. It can also provide employment and rekindle pride in customary ecological knowledge and local expertise amongst the younger generation.

There is also a need for caution, however. Land-use planners, conservation biologists and development workers working in this field have to ensure that they are not trapped by three romantic myths, and also that they do not become myth-makers themselves. These myths and an example of the myth-making are:

1. The myth that conservation areas comprise pristine African wilderness unchanged by people. Few, if any areas are pristine and unaffected by human influence.

2. The myth that indigenous peoples live in total harmony with nature. Customary conservation practices certainly do exist, but where demand for resources exceeds supply, or where commercial harvesting of slow growing, slow reproducing resources is involved, then species are overexploited and face local or regional extinction, whether medicinal plants or dye resources in southern Africa or forest on Easter Island felled by ocean-going colonists.

3. The myth that all indigenous peoples, or even specialist plant users such as herbalists within rural communities, have a profound, detailed knowledge of plants and plant uses. Levels of knowledge vary greatly, not only with age or experience, but within user groups such as herbalists.

4. Finally, we need to ensure that new myths are not created through misinformation. An example is the statement that '...we need to instruct [commercial medicinal plant] gatherers to put mud on a tree's wound when they peel bark—this is an ancient technique Zulus used to preserve debarked trees' (Mbanefo 1992). This gives three totally incorrect impressions, none of which benefit plant conservation. First, this is not, and has never been a traditional conservation practice. Second, it is unlikely to promote bark regrowth even if it was done. Third, it ignores the open access nature of medicinal plant resources in the wild and the economic incentives of commercial gatherers whose prime incentive, as poor and otherwise unemployed rural women, is to maximize economic gains from gathering before someone else does.

What is required is a balanced approach drawing on the strengths of both worlds to develop strong *in situ* and *ex situ* conservation programmes and provide practical development alternatives to take harvesting pressure off resources vulnerable to overexploitation. As Kingdon (1990) points out:
'*... Conservationists' answers should not lie in propaganda campaigns, which are generally seen for what they are, but in a shared growth of knowledge and debate. The minimal demands of local communities will include sustained, not ephemeral programmes of action in which their own people can find meaningful, decisive and dignified roles.*'

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Medicinal plants and their uses in Zimbabwe

S. MAVI

National Herbarium and Botanic Garden, P.O. Box 8100, Causeway, Harare, Zimbabwe.

ABSTRACT

The aim of this paper is to highlight our current knowledge of the medicinal uses of plants in Zimbabwe and to give pointers as to which plants need further investigations from a chemical, medicinal and pharmacological perspective. A survey of the medicinal uses of plants by 248 traditional practitioners was undertaken by the Faculty of Medicine, University of Zimbabwe, and the National Herbarium. Standard works that have been published in Africa concerning plants used in traditional medicine were examined in order to compare the information with our findings. Traditional methods of conservation are discussed. The flora of Zimbabwe contains just over 5 000 species of flowering plants. The plants that are known to be used medicinally number just over 500 which is 10% of this total. A plant was considered to be commonly used if utilized by at least 100 of the practitioners interviewed, even if used for a different complaint. Ninety species met this criterion. Initial studies have shown that some of the plants in traditional use possess useful pharmacological properties. Only long and complex studies can establish their safety and effectiveness. These studies may result in their utilization as either crude drugs or as raw materials in the manufacture of pharmaceutical products required in the promotion of primary health care. This, we hope, will contribute towards increasing the availability of essential drugs at a much reduced cost by the year 2000.

INTRODUCTION

A survey of the medicinal uses of plants by folk practitioners in both the urban and rural communities has been undertaken jointly by the Faculty of Medicine, University of Zimbabwe, and the National Herbarium.

The stimulus for this survey was provided partly by the fact that certain groups of herbalists were willing to impart their knowledge and partly by the realization that the longer one delayed a comprehensive investigation of this nature, the more information would be lost. The amount of traditional knowledge lost each year must be considerable as education of the rural population proceeds. Population increase also results in considerable pressure on the environment, and plants that are intensively utilized will inevitably become rare and eventually no longer used or will become extinct.

SURVEY ON MEDICINAL PLANTS

In 1972 Zimbabwean traditional practitioners were invited to come to Harare Hospital with the plants that they use. We recorded their medicinal uses and how they were administered. We also visited other centres in the country, collecting more plants and recording their uses. In all, 248 traditional healers were interviewed. When we obtained what we considered a good representative sample of the country's medicinal plants, we collected more information about them. The name of each plant was written on a separate card with symptoms of the illness, for which it was employed, as well as how it was administered. When this was done, we opened a file listing all plants that were used for the treatment of each symptom of disease. It was decided to analyse the standard works that have been published from various parts of Africa (South, Central, East and West) concerning the plants used by traditional practitioners of these areas in order to determine whether plants were prescribed for reasons similar to those in Zimbabwe. If a plant was reported to have a common use over a wide area, it deserved further scientific investigation.

During the survey we encountered a number of plants which the herbalists reported to be toxic if overdoses were administered. The police and hospitals also sent us specimens of plants which caused death when used as medicines.

RESULTS

The flora of Zimbabwe includes more than 5 000 species of flowering plants and ferns; of these, not many more than 1 000 have vernacular names. The fact that a plant has a vernacular name implies a use and visa versa. The plants that are known to be used medicinally number about 500 which is 10% of the total flora; but we included in this study only those plants that could be positively identified. We would speculate that, as more knowledge is accumulated and more ground covered, especially if Tonga and Shangaan uses are included, several hundred more species will be added to the total (Gelfand *et al.* 1985).

A plant was considered to be commonly used if it had been recorded to be used by at least 100 of the 248 practitioners interviewed, even if the use was for different complaints. We recorded 90 species of such plants, some of which are listed in Table 1.

Many of the plants have a limited geographical distribution, constrained by the type of the terrain, climate and altitude. About 232 of the plants said to be of medicinal value in Zimbabwe were also used for the treatment of medical complaints in Central, East and West Africa. Approximately 60 of these plants were employed in other countries to treat the same kinds of complaints as in Zimbabwe, although they were also used for other purposes. Seventeen of the species used in Zimbabwe and two other countries for similar complaints are listed in Table 2 (Gelfand *et al.* 1985). The remaining 208 plants were prescribed in Zimbabwe for complaints different from those in other countries.

TABLE 1.—Common medicinal plants in Zimbabwe

Name	Ailment/use
Albizia antunesiana	aphrodisiac
Albuca melleri	chitsinga
Alepidea amatymbica	abdominal pains
Aloe spp.	to dilate birth canal
Ansellia gigantea	depressed fontanelle
Aristolochia heppii	abdominal pains
Asparagus spp.	to dilate birth canal
Boophane disticha	to arouse spirits
Cassia abbreviata	abdominal pains
Chenopodium ambrosioides	convulsions
Cissampelos mucronata	painful menstruation, to prevent abortion, infertility
Crinum macowanii	to increase lactation
Datura stramonium	asthma
Dicerocaryum zanguebarium	measles
Dicoma anomala	abdominal pains
Dioscorea sylvatica	chitsinga
Elephantorrhiza goetzei	abdominal pains
Eriospermum abyssinicum	depressed fontanelle
Holarrhena pubescens	venereal diseases, aphrodisiac
Hydnora solmsiana	diarrhoea
Lippia javanica	cough
Mondia whitei	aphrodisiac, constipation
Neorautanenia mitis	detick dogs
Ocimum canum	panacea
Peltophorum africanum	panacea
Pouzolzia hypoleuca	to dilate birth canal
Pterocarpus angolensis	depressed fontanelle, bilharziasis, aphrodisiac
Rauvolfia caffra	high blood pressure
Securidaca longepedunculata	snake repellent
Solanum delagoense	venereal diseases
Sporobolus pyramidalis	depressed fontanelle
Tagetes minuta	to kill weavels
Trichilia emetica	emetic, purgative
Trichodesma physaloides	wounds
Triumfetta welwitschii	diarrhoea
Vernonia amygdalina	infertility in women
Warburgia salutaris	panacea
Zanha africana	abdominal pains, chitsinga
Zingiber officinale	abdominal pains

Of the 500 species used medicinally in Zimbabwe, 40 were reported to be toxic. Some plants may be toxic at one stage of their growth and comparatively innocuous at another. These plants are listed in Table 3 (Zimbabwe National Herbarium Poisonous Substance File, Unpublished).

PREPARATION OF MEDICINES

Often more than one plant will be used in a remedy by the N'anga and might be cooked with meat, beans or various portions of wild animals or insects. Furthermore, there is often a definite ritual that has to be strictly adhered to in order for the medicine to be effective. An illustration of this is a remedy for

TABLE 2.—Plants used for similar medicinal purposes in Zimbabwe and at least two other countries

Name of plant	Use in Zimbabwe	Use elsewhere	Country/area
Acalypha petiolaris	Wounds	Wounds Wounds	East Africa Burundi
Carissa edulis	Cough	Cough Cough	East Africa Zaïre
Cassytha filiformis	Dysmenorrhoea	Dysmenorrhoea Dysmenorrhoea	South Africa Namibia
Commelina spp.	Infertility	Infertility Barrenness in women	South Africa Zaïre
Dichrostachys cinerea	Abdominal pains	Stomach ache Stomach troubles	East Africa Zambia
Diplorhynchus condylocarpon	Venereal disease	Gonorrhoea Syphilis	East Africa Central Africa
Euphorbia hirta	Sore eyes	Ophthalmic remedy Eye troubles	East Africa Ghana
Hoslundia opposita	Abdominal pains	Stomach disorders Stomach	East Africa West Africa
Indigofera arrecta	Stomach pains	Abdominal pains	East Africa Zaïre
Mundulea sericea	Fish poison	Fish poison Fish poison	East Africa Ivory Coast
Oxygonum spp.	Whooping cough	Cough Cough	Tanzania East Africa
Securidaca longepedunculata	Headache	Headache Headache	Nigeria East Africa
Solanum delagoense and *S. incanum*	Snake-bite antidote Venereal disease	Snake-bite antidote Snake-bite antidote Syphilis Syphilis	Tanzania East Africa West Africa East Africa
Stereospermum kunthianum	Cough	Cough Cough	Tanzania East Africa
Strychnos spp.	Emetic	Emetic Emetic	South Africa Zambia
Terminalia sericea	Stomach disorders Bilharziasis	Stomach disorders Stomach disorders Stomach disorders Bilharziasis Bilharziasis Bilharziasis	East Africa Tanzania South Africa East Africa Tanzania South Africa
Vernonia amygdalina	Abdominal pains	Stomach disorders Stomach disorders	West Africa Zaïre

bilharziasis. The N'anga takes a lad with bilharziasis to a *Pterocarpus angolensis* tree which he cuts on its east and its west side. The patient licks the sap from each side daily until the bleeding stops. However, medicines are commonly given in the form of powders, decoctions, infusions or ointment (Gelfand *et al.* 1985).

TABLE 3:—Plants of known poisonous properties in use by traditional healers in Zimbabwe.

Abrus precatorius	*Erythrophleum suaveolens*
Adenia gummifera	*Euphorbia espinosa*
Aleurites moluccana	*E. ingens*
Aloe chabaudii	*E. matabelensis*
A. christianii	*E. schinzii*
A. excelsa	*E. tirucalli*
A. globuligemma	*Excoecaria bussei*
A. greatheadii	*Gloriosa superba*
A. ortholopha	*Gnidia kraussiana*
Boophane disticha	*Jatropha* spp.
Bowiea volubilis	*Maerua edulis (=Courbonia glauca)*
Capparis tomentosa	*Manihot esculenta*
Chenopodium ambrosioides	*Melia azedarach*
Clerodendrum ternatum	*Monadenium lugardiae*
Combretum erythrophyllum	*Neorautanenia mitis*
C. platypetalum subsp. *oatesii*	*Nerium oleander*
Croton megalobotrys	*Nicotiana glauca*
Cucumis africanus	*Phytolacca dodecandra*
C. anguria	*Ricinus communis*
C. hirsutus	*Securidaca longepedunculata*
C. metuliferus	*Solanum delagoense*
C. myriocarpus	*Solanum incanum*
Dalbergia nitidula	*Sphenostylis marginata*
Dalbergiella nyassae	*Spirostachys africana*
Datura stramonium	*Swartzia madagascariensis*
Dialium englerianum	*Synaptolepis alternifolia*
Dichapetalum cymosum	*Tephrosia vogelii*
Dioscorea spp.	*Trichilia emetica*
Encephalartos spp.	*Urginea altissima*
	Urginea sanguinea

CONSERVATION

To sustain the use of their flora, the traditional healers follow certain rituals when collecting their medicines. Failure to follow these rituals will render the medicine collected ineffective. When collecting bark, they do not ring-bark the trees, but only take the bark from one side of the tree, or only from the western and eastern sides. When collecting roots, not all roots are removed from the tree, but a few are left so that the tree can continue to grow. As for annuals, they collect some and leave some to set seed so as to allow regeneration. Again according to tradition no N'anga is allowed to collect medicine from a plant from which another N'anga has previously collected. N'anga rarely use fruits as medicine, so new plants can grow from the seeds (Mavi 1982).

CONCLUSION

Which of the 500 plants used medicinally have specific value in curing disease or alleviating common symptoms, we do not yet know. Experimental research is now required to learn their pharmacological properties. We hope that medicinal plants employed by N'anga will prove to be of help to mankind. Initial studies have

shown that some of these plants possess useful pharmacological properties (Graven 1992) and only long and complex studies can establish safety and effectiveness. These studies may result in their utilization as either crude drugs or as raw material in the manufacture of pharmaceutical products required in the promotion of primary health care. This could contribute towards increasing the availability of essential drugs at a much reduced cost by the year 2000.

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Herbaria: human and infrastructural needs in southern Africa

H. BAIJNATH and A. NICHOLAS

Department of Botany, University of Durban-Westville,
Private Bag X54001, Durban, 4000 South Africa.

ABSTRACT

Herbarium facilities in southern Africa are shown to be inadequate and unable to address or find solutions to the environmental and social challenges of the 21st century. If the subcontinent is to meet the challenges of the future, attitudes towards these environmental resources will have to change. Herbaria with their dual nature (friend to the environment and friend to the people) have a pivotal role to play in this regard. This role is examined and suggestions made for improving the herbarium infrastructure of the region.

INTRODUCTION

Plant species are genetic resources that are capable of generating funds on a sustainable basis. They are also important components in the many cycles which maintain the life-supporting environment of the earth's biosphere. As the human population increases, so do the demands made on these resources. The region's survival will depend on the wise utilization and sustainable management of this genetic resource. Herbaria in the region have a role to play in helping to achieve this. It is therefore of concern that a survey of existing herbarium infrastructure in the subcontinent shows it to be inadequate. Due to a number of negative forces (the lack of funds and general ignorance being the two greatest), herbarium facilities are insufficient, and staff numbers and morale are low. As a result, herbaria and their associated taxonomic staff are unable to play any meaningful or constructive role in helping to find solutions to present environmental problems.

Herbaria within southern Africa need more support and a change in attitude towards them by other plant-related sciences. Furthermore, larger national herbaria, which are both phylogenetic models of the subcontinent's vegetation as well as vast storage and retrieval systems for plant-related information, need to be built up as centres of excellence.

The time has come for society to take a fresh look at herbaria and the important role these institutions will have to play in the future of the subcontinent, both in relation to its biosphere and its economy.

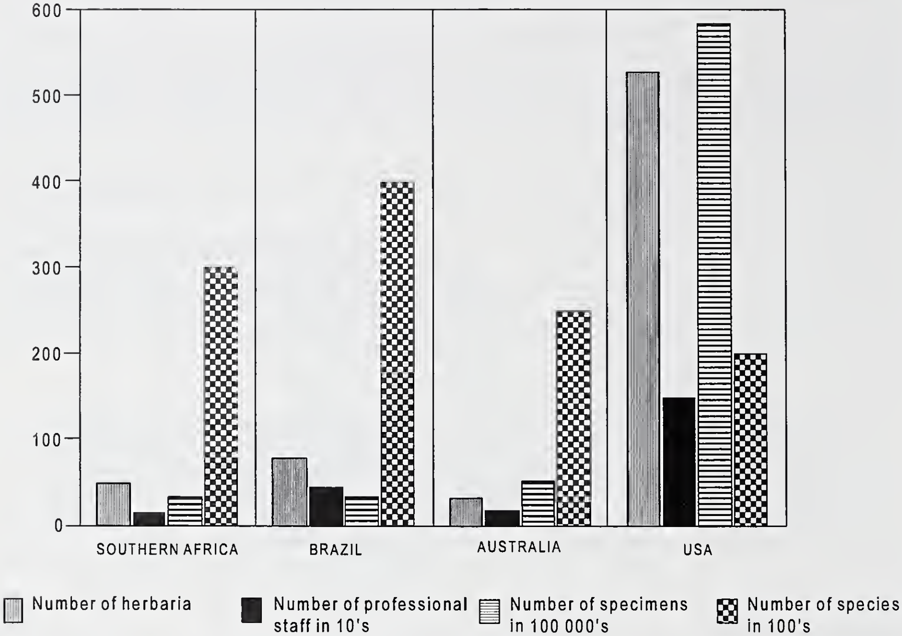

Figure 1.—A comparison of herbarium infrastructure and plant diversity in southern Africa, Brazil, Australia and the United States of America.

THE DUAL NATURE OF HERBARIA

Herbaria should be seen as both scientific arks of plant diversity and generators of wealth. The herbarium resources of any country, or region, should be seen in terms of this duality, viz. in the context of that country's plant diversity (its genetic wealth) and the sophistication of its plant-based industries (its economic wealth). The greater the plant diversity and the more sophisticated its plant-based industries, the greater should be the availability of herbarium resources.

The first of these two factors is probably self-evident—countries with more species should have more herbaria. However, this is not always the case and some areas that have a high plant diversity, such as southern Africa, have extremely poor herbarium facilities.

National economic goals and objectives are, unfortunately, seldom considered when planning or expanding herbarium facilities. Sophisticated economies with many plant-based industries rely more heavily on the names of plants and their associated data than do less sophisticated economies. As a result, in technocracies all sorts of industries interface with herbaria, and in such countries plant

names and their associated information generate jobs and money. This can be seen in countries such as the USA which, although not particularly rich in genetic resources (Figure 1), has an extensive and sophisticated herbarium infrastructure when compared to southern Africa (which is species-rich but poor in plant-based industries). Developing countries hoping to establish sophisticated economies or to become technocracies will have to develop their botanical infrastructure, including herbarium facilities, to achieve this goal. Southern Africa will have to develop a sophisticated and vibrant, money-generating regional economy if it is going to supply its burgeoning population with food, employment, housing, education and at the same time uplift living standards in the subcontinent. To do this, no resource should be left unutilized or underutilized; this includes the genetic wealth of the subcontinent. However, this utilization must be wise and sustainable if its economic and social benefits are to be long-lasting.

The employment and money-generating potential of the subcontinent's indigenous flora is vast:

- Indigenous plant resources can play a part in the production of chemicals, medicines (Miller & Brewer 1992) and foods (Toriyama 1992).
- They possess a wealth of genes that may be used in the many emerging industries using genetic engineering.
- They are pivotal to a successful ecotourist industry (Richards 1971).

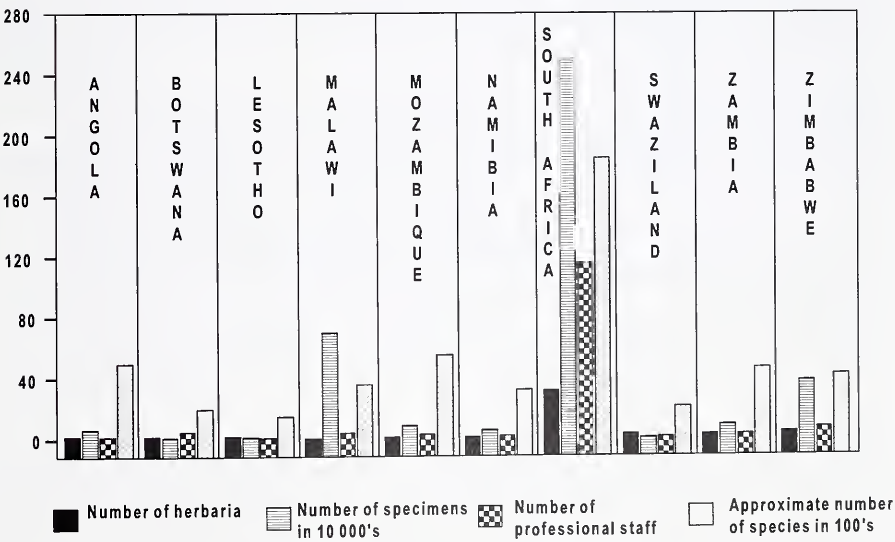

Figure 2.—A comparison of herbarium resources with professional staff levels and plant diversity in southern Africa.

TABLE 1.—A comparison of herbarium resources in southern Africa with species diversity, population size and economic performance. Herbarium resource figures obtained from Holmgren *et al.* (1990) (unbracketed) and Hedberg (1990) (bracketed). Angolan herbarium information is for 1991 and was kindly supplied by E. Matos (pers. comm.). * = estimated numbers of species.

Country	Category									
	Herbarium resources						Plant and land resources		Populations and economic resources	
	Number of herbaria	Number of specimens	Number of professional staff	Number of publications	Number of associated botanical gardens	Herbarium species ratio	Approximate number of species	Area in km^2	Population size	GDP in PPP$
ANGOLA	3	85 000	1?	0	0	1 667	5 000*	1 246 700	9 767 000	800
BOTSWANA	2(4)	12 500 (29 000)	5(1)	0	0(1)	1 000	2 000*	581 730	1 300 000	2 500
LESOTHO	2	16 000 (14 000)	1(2)	0	1	776	1 553	30 355	1 700 000	1 400
MALAWI	1	70 000 (± 85 000)	4	0	0(1)	3 600	3 600*	118 484	8 022 000	600
MOZAMBIQUE	2	86 132 (90 000)	3	2	1	2 750	5 500*	801 590	5 326 000	1 100
NAMIBIA	1	55 000	2	0	1	3 210	3 210	824 292	1 500 000	1 500
SOUTH AFRICA	32	2 501 148	115	10	8	578	18 500	1 221 031	34 492 000	5 500
SWAZILAND	(3)	– (4 600)	–(1)	–	–(0)	706	2 118	17 363	763 000	2 100
ZAMBIA	3	86 500	3(1)	0	0	1 533	4 600*	752 614	7 804 000	900
ZIMBABWE	4	374 200	7	4	3	1 050	4 200*	390 580	9 122 000	1 400
TOTALS	53 (55)	3 291 080 (3 324 448)	142 (137)	16	16 (14)	N/A	N/A	5 984 739	79 796 000	N/A

- They are of horticultural importance and can be used to create human-friendly environments in cities and homes (Shibata 1992).
- Indigenous plants are the base of the food chain on which the subcontinent's meat (mainly cattle) supply relies.

All these industries eventually interface with herbaria and rely on herbarium staff and taxonomists for their success. We must therefore ask the question: are the herbarium facilities in the southern African subcontinent capable of helping us to meet the challenges of serving the plant-based industries the subcontinent needs as it develops and expands during the next century? To answer this question, we must first look at what facilities we have within the subcontinent and then compare these to facilities in other successful or developing economies.

HERBARIUM RESOURCES IN SOUTHERN AFRICA

Herbarium resources in the subcontinent are summarized in Table 1. To place these facilities in perspective as regards plant diversity and economics, they are compared in this table with species richness as well as population and economic information. South Africa, which is the most species-rich country in the region (with some 18 400 species) and also has the most sophisticated economy (with a GDP in PPP$[1] of 5500), has the largest number of herbaria (32) as would be expected (Figures 2 and 3).

The countries that appear to be in the best position after South Africa, are Malawi and Zimbabwe. Countries like Angola, Mozambique and Zambia with fairly high levels of plant diversity have, in comparison, extremely poor herbarium facilities.

On an economic level, a number of countries adjacent to South Africa, namely Botswana, Swaziland and Lesotho, have (for the subcontinent) relatively strong economies (as judged by their GDP in PPP$). Despite this, their herbarium facilities are fairly poor.

In terms of the number of professional staff in relation to human potential (as judged by comparison with overall population) Botswana leads with one professional staff member for every 260 000 head of population. South Africa is next (1 in every 348 000), followed by Namibia (1 in every 750 000) and Swaziland (1 in every 763 000). Angola is worst off with about 1 in every 4.8 million head of population, followed by Zambia (1 in 2.6 million) and Malawi (1 in 2 million).

Patterns of funding are also interesting. In most instances, herbaria are government-supported at either the national level (government or state universities) or in the case of South Africa, through local or provincial government. In

[1] Gross Domestic Product [GDP] per capita in Purchasing Power Parities [PPP$] expressed in international dollars.

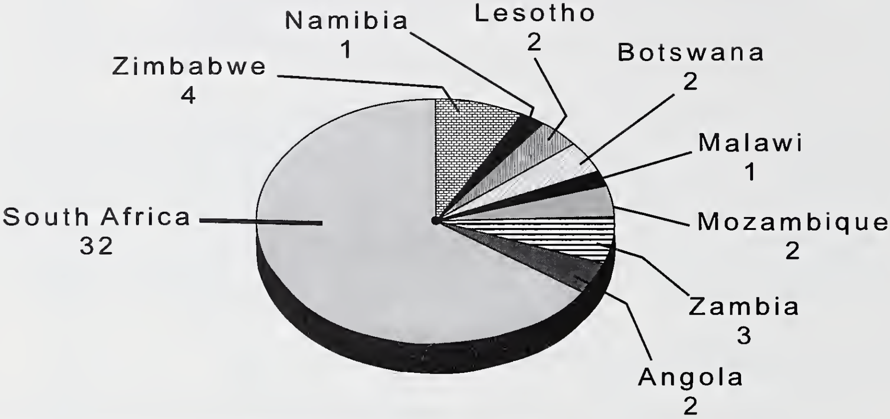

Figure 3.—Number of herbaria in southern African countries.

both South Africa and Zimbabwe there are also a number of parastatal herbaria and in the case of South Africa one privately funded herbarium.

Hedberg (1990, 1991), after visiting a number of southern African herbaria, laid down the minimum requirements needed for each national herbarium in the subcontinent (Table 2). However, if one examines herbarium facilities in the subcontinent, it can be seen that most herbaria fall short of these minimum requirements (Table 3). The national herbaria of Harare (SRGH)[2], Pretoria (PRE) and Zomba (MAL) are well placed in terms of herbarium facilities, but if compared to the plant diversity and economies of these countries, they must be seen as insufficient.

Besides the lack of basic facilities, it is also obvious that the subcontinent does not have enough trained taxonomists or herbarium technicians. The lack of a good herbarium infrastructure can be clearly seen if facilities in the subcontinent are compared with those in regions of similar size elsewhere in the world.

HERBARIUM FACILITIES IN SOUTHERN AFRICA COMPARED WITH REGIONS ELSEWHERE IN THE WORLD

Table 4 summarizes and compares herbarium resources, plant diversity, human populations and economic factors in southern Africa with those in Australia, Brazil and the USA[3].

[2] Herbarium abbreviations according to Holmgren *et al.* (1990).

[3] The authors feel that it is of little importance, other than economic, that these regions are represented by single countries. The pronounced federal or provincial infrastructure of each makes the comparison with southern Africa feasible.

TABLE 2.—Minimum requirements for each national herbarium in southern Africa as outlined by Hedberg in 1991.

- Adequate localities.
- Herbarium cupboards.
- One large freezer for elimination of insect attacks on specimens.
- Two taxonomists with M.Sc. or Ph.D. in systematic botany.
- Adequately trained herbarium technicians.
- One 4-wheel drive vehicle for field trips.
- Sufficient earmarked field work grants.
- Grants for taxonomists and technicians to participate in regional and occasionally international conferences.
- Increased library grants to establish basic but workable botanical libraries.
- A botanist trained in computerizing botanical data.
- A computer with hardware and software suitable for storage and retrieval of large amounts of botanical information.
- Each herbarium should have its own earmarked grants.

At first the lower number of herbaria in Australia (= 32) would seem to make southern Africa seem adequate (= 49). However, a comparison with population numbers, Australia with 17 million people and southern Africa with 80 million, shows Australia to be advantageously placed. This finding is confirmed if plant diversity (Australia with 20 000 species versus southern Africa with 30 000 species), specimen numbers (5.3 million versus 3.4 million) and staff numbers (174 versus 142) are considered (Figure 1). In Australia, for every 92 000 individuals, 1 is employed in a professional capacity in a herbarium, while in southern Africa this ratio is only 1 in every 704 000 individuals—that is seven times lower than in Australia. In Brazil this ratio is 1 in every 226 000 people (3 times higher than in southern Africa) and in the USA it is 1 in every 169 000 (4 times higher than in southern Africa). If the number of herbaria with associated botanical gardens and the number producing journals are considered in terms of both regional plant diversity and human population, then southern Africa comes off worse on all these facilities too.

It is obvious from economic comparisons that the herbarium facilities in South Africa alone will need to be increased about six times if they are to compare with other economically sound regions of the world such as the USA, which, although not particularly rich in plant genetic resources, has an extensive and sophisticated herbarium infrastructure. As a direct comparison, we can also consider Japan (surface area = 377 727 km^2) and Zimbabwe (surface area = 390 759 km^2) which have almost equal species diversity (4 000 and 4 200 respectively), yet Japan with its sophisticated economic base has 10 times more herbaria than Zimbabwe (40 versus 4).

Unlike southern Africa and Australia, both Brazil and the USA have a large number of privately funded herbaria. While it would be ideal for southern Africa to move in this direction due to reduced governmental support, it is unlikely that private foundations will be rich enough to supply the high levels of funding that are required.

TABLE 3.—Comparison of some basic facilities needed for running both an efficient and effective herbarium (Hedberg 1990). Angolan information is for 1991 and was kindly supplied by E. Matos (pers. comm.).

Herbarium abbreviation (country)	Library facilities	Microscopes	Vehicles	Taxonomic staff	Money for field work	Computer facilities
GAB (Botswana)	Insufficient	Lacking	Lacking	Lacking	Lacking	Lacking
UCBG (Botswana)	Needs improvement	Lacking	Lacking	1	Lacking	Lacking
NUL (Lesotho)	Not seen	Lacking	Lacking	Insufficient	Lacking	Lacking
MOA (Lesotho)	Insufficient	Lacking	Lacking	Insufficient	Lacking	Lacking
MAL (Malawi)	Much more needed	Fine	Plentiful	More wanted	Sufficient	Available
INIA (Mozambique)	Needs additions	Probably needed	Lacking	At least 2 more needed	Lacking	Lacking
LMU (Mozambique)	Small	Available	Lacking	More needed	Lacking	Lacking
Malkern (Swaziland)	Small–substantial increase desirable	Lacking	Lacking	3 assistant curators needed	Lacking	Lacking
UZL (Zambia)	Not seen	Not seen	Insuffient	1	Lacking	Not seen
MRSC (Zambia)	Adequate?	Lacking	Lacking	Lacking	Lacking	Lacking
SRGH (Zimbabwe)	Money needed for new books, journals and micro-fiche	More needed	More required	More needed	More needed	Lacking
PRE (South Africa)	Good but should continue to be built up	Available but more needed	Available but 4-wheel drive vehicle needed for field work	More needed if centre of excellence is desired	More needed	Excellent
LUA (Angola)	Inadequate	Lacking	Lacking	None	Lacking	Lacking
LUAI (Angola)	Insufficient	Lacking	Lacking	Lacking	Lacking	Lacking

TABLE 4.—A comparison of herbarium resources, plant diversity, human populations and economic factors in southern Africa, Australia, Brazil and USA

Variable	Southern Africa	Australia	Brazil	USA
Herbaria	49	32	79	526
Number of specimens (Holmgren *et al.* 1990)	–	5 300 600	3 186 539	60 421 964
Number of specimens (personal research)	3 383 980	5 290 600	3 196 539	58 467 546
Number of professional staff	142	174	442	1 479
Population	80 000 000	17 000 000	100 000 000	250 000 000
Number with associated gardens	14	10	17	103
Number producing journals or periodicals	15	17	68	127
Government-funded university or college herbaria	20	10	6	302
Central or federal government-funded herbaria (including parastatal)	20	7	50	43
Local government-funded herbaria	2	15	10	42
Total of government-funded herbaria	48	32	66	387
Privately funded university or college herbaria	0	0	1	117
Privately funded herbaria	1	0	7	31
Total number of privately funded herbaria	1	0	8	148

Using the number of specimens in herbaria (as a measure of herbarium facilities) and comparing this with species number (as a measurement of plant diversity), comparisons of southern Africa with the rest of the world show the herbarium infrastructure of the subcontinent to be insufficient (Table 4).

The poor herbarium facilities of the subcontinent are, to a large extent, due to the many negative forces acting on their development and growth.

NEGATIVE FACTORS AFFECTING HERBARIA IN SOUTHERN AFRICA

The negative forces operating on the proper functioning and growth of herbaria in the subcontinent are summarized in Table 5. These forces can be summarized under four main headings:

a. Lack of adequate funding

With human populations in the subcontinent expanding faster than national economies, poverty is not only widespread but increasing. This has been aggravated by the general economic recession that has gripped the subcontinent for the past four years. Under such conditions, governments are left with little choice but to divert resources to solving problems associated with poverty (Wilson & Ramphele 1989). This has led to the underfunding of science in general (including herbaria) which is, understandably, not seen by present governments as a priority. In fact, herbaria in the subcontinent have either had to remain static for some time or have been forced to reduce their operations. The latter option has in turn lead to a cut in staff levels by some herbaria. The present perceptions

held by funding bodies are unfortunate because, as has been pointed out, *herbaria are an essential component of the economy.* They have an important part to play, not only in helping to build plant-related industries (which will in the long term create employment and so help alleviate poverty), but also in the study and sustainable management of rapidly dwindling genetic resources that are vital for the long-term survival of economies in the subcontinent.

b. Negative attitudes and lack of awareness towards herbaria and taxonomy

One of the major negative forces impacting on the establishment, maintenance and expansion of herbaria is the negative attitude towards them and towards taxonomy sometimes held by other scientific disciplines, especially other plant-related sciences. This antagonism can, in part, be blamed on:

- The historical fight for funds between the various subdisciplines of botany.
- The fact that taxonomy is not seen as an empirical science.
- A lack of insight into the function and place of herbaria within society.

As a result, the future of taxonomy has been debated in the scientific press (Stirton *et al.* 1990). Also, attitudes within universities have often led to a reduced emphasis on the teaching of taxonomy in the university curriculum. Some South African universities no longer employ properly trained or full-time lecturers in taxonomy or plant systematics. The lack of exposure of students to motivated systematists and innovative taxonomy has resulted in those students interested in a botanical career choosing other subdisciplines. This has in turn resulted in a decrease in the number of taxonomists reaching the job market. Until now such losses in trained taxonomists have kept pace with the ever decreasing number of posts available to them. As a result, the demise of taxonomy has virtually gone

TABLE 5.—Negative forces operating on the proper functioning and growth of herbaria in southern Africa

- Lack of adequate funds.
- Lack of trained taxonomists and herbarium technicians.
- Negative attitudes towards herbaria and taxonomy from other scientific disciplines, especially other plant-related sciences and funding bodies.
- Work at herbaria is poorly paid and therefore does not attract highly motivated employment seekers.
- Lack of awareness about herbaria (their function and contribution to society) by the community and by governments.
- General economic recession.
- Lack of support that can only be supplied by a sophisticated economy and sophisticated social infrastructure.
- Political instability in some countries.
- Inadequately trained managements that lack 21st century vision and planning.
- Poor herbarium facilities and frustrated, overworked staff.
- Lack of communication between herbaria in the subcontinent.
- Negative attitudes of some taxonomists and herbarium workers who are unwilling to move with the times.

unnoticed. The situation has been exacerbated by the fact that work at herbaria is often poorly paid and therefore does not attract highly motivated employment seekers. In South Africa workers in many other industries, such as the computer industry, are able to earn salaries twice that of taxonomists employed in the botanical sector. However, it is not only other plant sciences that are to blame for the negative attitudes affecting herbaria—a lack of awareness (about herbaria and their important function) by governments (local, regional and national) and by the general public has also contributed to the situation.

However, with the continuing expansion of plant-related industries (which rely on correctly named plant specimens) and with plant species becoming extinct at an alarmingly high rate in comparison to the taxonomic manpower available to survey and handle them (Heywood 1974), there is little doubt that taxonomy and herbaria will be called upon to play a more prominent role again. Miller *et al.* (1989) also outlined, in detail, the important role systematics has to play in the conservation of biodiversity.

Botanical scientists need to educate governments, other scientists and the general public regarding the important role they have to play in this subcontinent's future economic development and in helping to uplift the living standards of its people.

c. Political, social and economic instability

Many countries in southern Africa have for decades suffered from political instability and the resulting social and economic uncertainty that ensues from this. Angola (of which the land area exceeds that of South Africa) is a point in case. The herbarium building at Huambo (which houses priceless older collections) has been reported to be damaged as a result of the civil war in that country (E. Mato pers. comm.). It is a brave and dedicated botanical community that continues to maintain herbaria infrastructure under such deprivation and danger. Little thought can be given to improving or expanding herbaria under these conditions. In fact, it would seem that adequate herbarium structures (as found in the USA) are often possible only where political stability has enabled the development of sound economies and sophisticated, peace-loving societies.

d. Outdated attitudes of many taxonomists and herbarium workers themselves

Much of the blame for the present negative attitude towards taxonomy and herbaria can be placed squarely at the feet of workers in this field themselves. Many such workers have failed to:

- educate others concerning their important role and function;
- keep pace with advances in technology as well as changes in social and scientific perspectives and paradigms.

Taxonomy is learning, to its cost, that it cannot hide behind closed herbarium doors hoping that the modern world will pass it by and not disturb the *status quo*. There is an urgent need for systematists and their associated herbaria to reform themselves, and quickly, if they are to be taken seriously by other sciences and also be in a position to play any meaningful role in the world of the next century.

THE ROLE AND FUNCTION OF HERBARIA

The functions of herbaria, particularly national herbaria, are numerous and varied (Hedberg & Hedberg 1992a). These institutions can no longer be seen as dusty collections of little use, viz. artifacts of the Victorian era's obsession with collections. The major functions of herbaria (Figure 4) are discussed below:

a. Specimen collection

Plant specimens supply the raw data necessary for botanical research. Specimen collection should therefore not be seen as a luxury, but as a necessity. One of the major functions of herbaria should be the systematic sampling of the plant diversity of the subcontinent, including infraspecific variation. Stuessy (1993) predicts that worldwide there are approximately 50 000 undescribed species of flowering plants and that if these become extinct before we can describe and study them, they will remain as irreplaceable gaps in our knowledge (Heywood 1974). As a result, one specimen of a taxon should be seen as better than none at all.

As a corollary to conservation efforts, there should also be active programmes for the collection of rare and endangered species. Herbaria are in reality arks of plant diversity (Stirton *et al.* 1990) and are, if treated properly (Liston *et al.* 1990; Adams *et al.* 1992), sources of extractable DNA (Giannasi 1992). It is to be hoped that at some future time the DNA of extinct plant species housed in herbaria may be used to recreate these plants. As such, plant collections in herbaria should be seen as one of the most important resources on earth today.

All plant-related science, including Environmental Impact Assessments (EIAs), have validity only if voucher specimens, on which these studies are based and which render them both accountable and repeatable (Stearn & Chambers 1960), are housed and maintained in herbaria.

Depending on the type of data that is required from them, plant collections may be of many kinds. Different categories of collections include herbarium specimens, specimens preserved in liquid (wet collections), seed or germ plasm collections, carpological or fruiting material, collections of living material for cultivation in greenhouses and botanical gardens, and special collections for specific kinds of research (such as anatomy and chemotaxonomy).

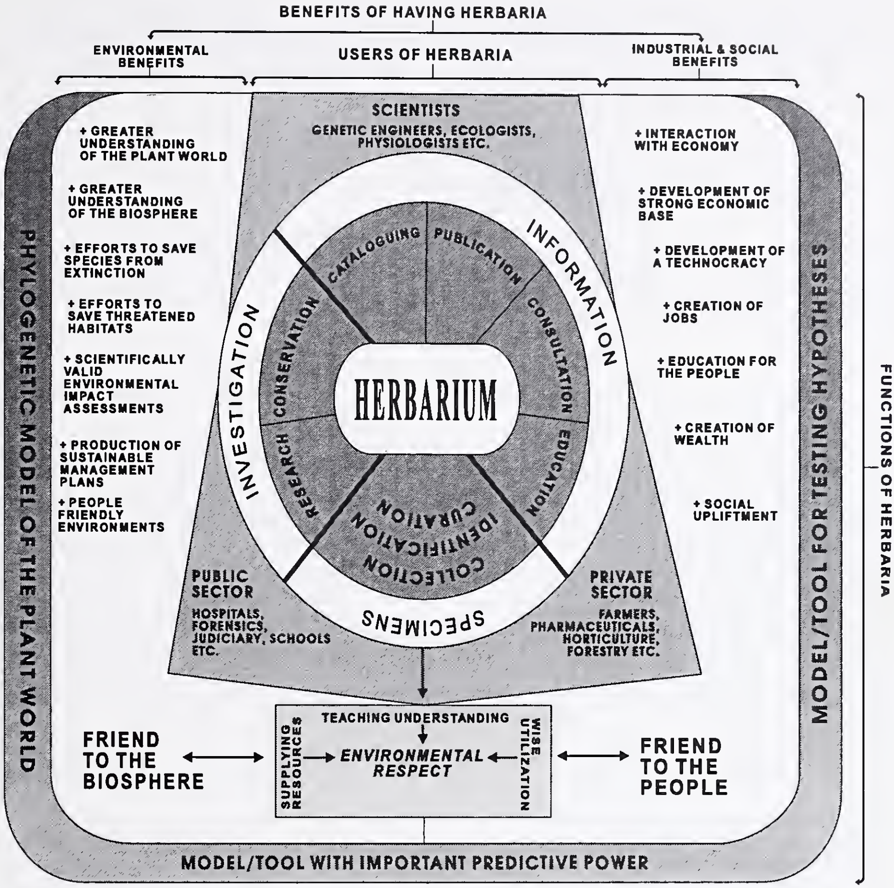

Figure 4.—Diagram illustrating the functions, users and benefits of herbaria.

b. Identification of plant specimens

This requires highly trained staff, often with a number of years of experience. Names are needed by three main sectors of society:

- *The scientific community,* especially numerous phyto-related sciences such as conservation, chemistry, ecology, physiology and genetic engineering (Hodgkin & Debouck 1992).
- *The private sector/industry.* Correct, valid names are required by the pharmaceutical industry, horticultural industry, agriculture (Duvick & Brown 1989), forestry and many others.

- *The public sector.* Major users of plant names in this sector include hospitals (in cases of plant poisoning), schools, universities, forensic departments, the judicial system, municipality-controlled nature reserves, botanical gardens and the general public.

c. Curation and maintenance of collections

Existing collections need to be administered, updated, maintained and expanded so that they continue to meet international standards (Table 6). This requires properly trained technical staff.

d. Cataloguing

Cataloguing of plant diversity and its associated data is an essential function of herbaria. End products include: flora checklists (local, regional and national), prodromal floras, computer-generated flora approximations, nomenclatural lists (e.g. plant author names), taxonomic lists (e.g. lists of ethnic names), catalogues (e.g. weed or invader plant inventories), bibliographies and indices.

TABLE 6.—A summary of curatorial activities undertaken by herbarium staff

CURATION AND MAINTENANCE

Updating, maintaining and expanding existing collections so that they meet international scientific standards. Curation and herbarium hygiene require properly trained technical staff. What is involved:

- Drying and pest eradication of newly collected specimens.
- Mounting of specimens—including labels.
- Mounting of photographs, pamphlets and correspondence.
- Incorporation of new specimens into the collection.
- Regular inspection of cupboards for insect pests.
- Preparation of genus covers and species covers.
- Curation of ancillary collections: spirit collection, seed collection, carpological collection, wood collection, illustration and slide collection.
- Incorporation of new information from on-going scientific research, particularly taxonomy*.
- Rearrangement and updating of specimens to fit with new taxonomic systems*.
- Production of checklists*.
- Selection of specimens for loan to other institutions*.
- Renovating old or damaged specimens.
- Refiling specimens, particularly returned loans.
- Processing of duplicate specimens.
- Dispatch of specimens to other institutions.
- Specimen administration: accessioning, recording and dispatch.
- General administration.
- Typing of identification lists, cupboard lists etc.
- Updating necessary databases associated with the specimens.
- Collection of specimens/expansion of collections.

* Usually done in conjunction with or under the supervision of taxonomists.

TABLE 7.—One of the major functions of herbaria should be the study or research of the plants they collect, catalogue and grow. Such research should include:

■ Alpha, beta and gamma taxonomy	■ Genetics
■ Anatomy and micromorphology	■ Herbarium hygiene and curation
■ Botanical history	■ Horticulture
■ Chemotaxonomy	■ Micro- and macrosystematics
■ Cladistics and numerical taxonomy	■ Nomenclature
■ Conservation	■ Ontogeny
■ Cryptogamic studies	■ Palaeobotany
■ Cytology	■ Palynology
■ DNA and RNA profiles	■ Phytogeography
■ Ethnobotany	■ Pollination biology
■ Evolutionary botany	■ Reproductive biology
■ Floristics	■ Speciation

Taxonomists and systematic botanists should be encouraged to collaborate with other research disciplines such as:

• Chemistry	• Genetic engineering	• Microbiology
• Biochemistry	• Geology	• Pharmacology
• Ecology	• Horticulture	• Physiology

e. Research

One of the major functions of herbaria should be the study of the plants they collect, catalogue and grow. Table 7 lists the type of research that should be undertaken by herbaria. However, systematic botanists should also be encouraged to collaborate with other research disciplines.

f. Conservation

As a corollary to the writing of floras and monographs, herbarium staff should be actively engaged in conservation efforts and research. In fact, Stace (1989) states that: ‘For too long the priorities in conservation have been dictated by ecological principles alone, even though taxonomic principles are at least equally relevant.’ They should also participate in national and international conferences on the environment, conservation and biodiversity and assist with the compilation of checklists, *Red data books* and EIAs. They can also play a vital role in the study of the floristics of threatened plant communities (as these are essentially the major units with which conservationists should be concerned) and in the collection and research of threatened plants. On the legal front they should work with the legislature and with global efforts such as CITES.

g. Information and consultation

Herbaria, whether small or large, generally play an important role in supplying other researchers, industry and the public with plant-related information. They are a significant element in the formulation of environmental plans for the sustainable use of plant resources. Trained herbarium staff are well qualified to contribute to committees or boards involved with issues relating to the environment, biodiversity or the biosphere itself. This is because such herbarium staff have access to multifarious plant-related information and as a result often have a deeper insight into the complex workings of plants and plant communities than more specialized researchers. Taxonomists may also be authorities on regional floras or have special knowledge of whole plant families. Their use in an advisory or consultative capacity should therefore be encouraged and not overlooked. They could, with great benefit, be used to help produce management plans for natural as well as man-made environments. In particular, they have an important role to play in the production of EIA studies, especially in the naming and housing of specimens on which these assessment reports are based.

h. Publications

Herbaria need to publish plant-related research and information in the form of checklists, pamphlets, research papers, floras, monographs, scientific and popular botanical books, congress proceedings and videos. In fact, both Stace (1989) and Stuessy (1993) emphasize the important part monographs should play in light of the present extinction crisis and urge that the production of these be made a priority.

i. Education

Herbaria must become actively involved with educating the public (of all ages) on matters pertaining to the region's plant diversity, as well as its wise utilization and sustainable management. To do this, they need to:

- interface with and produce material for use by the media (printed matter, radio and television);
- interface with local and regional government; and
- make an effort to reach out to communities (rural, suburban, townships and informal).

To achieve this, national herbaria require a highly motivated public relations officer or public relations department. Talks to schools, technikons, universities (as well as to the general public) should be presented on the important role herbaria have to play as friend to both the biosphere and to the economy. National herbaria should also play a role in structuring the national education curriculum where this relates to botanical issues. Herbaria should be active members of the

society that surrounds them. Through education they can help create a positive regional and national attitude towards the environment.

Summary

The above discussion clearly illustrates that herbaria are more than mere static collections. They are, in fact, important tools that are needed to collect, study and catalogue the green world we live in but, more than this, they interconnect with industry and also have a part to play in education. The development of a strong industrial base and improved education (accompanied by a rise in living standards) are therefore indirect but major beneficial influences herbaria have on society.

HERBARIA AS IMPORTANT SCIENTIFIC MODELS AND AS STORAGE AND RETRIEVAL SYSTEMS FOR MULTIFARIOUS PLANT-RELATED DATA

Herbaria can be arranged in three major ways:

- *Alphabetic at all levels*—family, genus and species.
- *Phylogenetic.* The most commonly used systems are those of Bentham & Hooker (1862–1883) and Engler & Prantl (1887–1915), the latter arranged by De Dalla Torre & Harms (1900–1907). In present times, updated versions of these two systems are often used. Species are arranged phylogenetically according to various major revisions or monographs.
- *A combination of alphabetic and phylogenetic.* Many herbaria have families, and often genera, arranged phylogenetically but species arranged alphabetically.

Alphabetic arrangements are usually used by small herbaria or by those not actively engaged in botanical research. They are systems of convenience and convey minimal information to the user. However, to be either an effective teaching tool or research collection, herbaria need to be arranged phylogenetically. Only if phylogenetic, can these collections become useful models of the complex green world that we live in and, therefore, be of predictive benefit. Such phylogenetically arranged herbaria should also be seen as a complex set of hypotheses which can be continually tested by research workers and then, if necessary, adjusted to conform with new data.

However, such phylogenetically arranged herbaria become useful models only when they contain about 80% of the taxa represented in any given area. The Natal Herbarium (NH) in Durban, although small (with some 90 000 specimens), contains over 80% of the taxa occurring in Natal and can therefore be considered a phylogenetic model of the vegetation of the Natal Province. However, more often than not it is the larger, well curated herbaria that are the most useful models. Herbaria such as the herbarium of the Royal Botanic Gardens Kew (K) outside London with about 6 million specimens, the Komarov Botanical Institute (LE) in

St Petersburg with some 5.7 million specimens and the New York Botanic Garden with 5.3 million specimens, may be seen as models of the world's phytosphere. This makes them possibly the largest and most valuable scientific models presently available to mankind.

On a more regional basis, the National Herbarium in Pretoria (PRE) may be seen as a model of the flowering plant realm in southern Africa, the National Herbarium in Harare (SRGH) may be considered a model for Zimbabwe, and the National Herbarium at Zomba (MAL) a model for the vegetation of Malawi. At this time, it is doubtful whether other herbaria in southern Africa have reached the size that makes them qualify as important research or scientific models, although some older, smaller herbaria are the repository of valuable, historical type collections.

Larger herbaria, such as MAL, PRE and SRGH, must also be seen as vast storage and retrieval systems for multifarious plant-related information. Such plant-related data are obtainable from two major sources within these herbaria: from the many kinds of specimens themselves and also from the valid and up-to-date plant names they supply (Table 8). However, these are not the only sources of information within these large herbaria; other important sources include associated libraries, living collections in attached botanical gardens and, a much ignored source, the professional staff themselves. Experienced herbarium staff, many of them with a life-long and therefore intimate knowledge of regional floras, are a vast store of unpublished information that is often overlooked.

TABLE 8.—Data obtainable from large herbaria. These herbaria are vast storage and retrieval systems for multifarious plant-related information.

Data obtainable from herbarium specimens:

■ Anatomical information	■ Geological information
■ Conservation status	■ Habit
■ Distribution information	■ Habitat information
■ DNA samples (the possibility to recreate extinct plants may exist at some future time)	■ Life cycle information
■ Ecological information	■ Micromorphological information (including pollen)
■ Economic information	■ Morphological information
■ Ethnobotanical information	■ Pollination and reproductive biology
■ Genetic anomalies	■ Taxon variation

Data obtainable from species, genus and family names supplied by herbaria. All the above data plus:

• Chemical information	• Genetic information
• Cytological information	• Medicinal/pharmaceutical information
• Fossil information	• Physiological information

The fact that these larger, systematically arranged herbaria are immense phylogenetic models of the plant world and also vast storage and retrieval systems for plant information makes them tools with great predictive power. As such they are essential to any country that has or strives to have a sophisticated economy. They are also important to countries concerned with conserving, utilizing and managing their biodiversity. On the global front they are important to a world trying to understand and maintain a life-supporting biosphere.

SELECTED HERBARIA AS CENTRES OF EXCELLENCE

Southern African herbaria that are both phylogenetic models of the subcontinent's flora and also large storage and retrieval systems for plant information, are important regional resources that need to be developed into centres of botanical excellence. To achieve this, these herbaria need to be built up and sustained financially on a fairly broad front. Some of the requirements needed for creating such centres of excellence are outlined below:

Staff

Adequate, highly motivated staff are required. This must include necessary specialist support staff (often nonbotanical).

Laboratories

Establishment of sophisticated laboratories for the study of anatomy, chemotaxonomy, conservation, cryptogamic botany, cytology, ecology, ethnobotany, genetics, germ plasm, medicinal plants, micropropagation, molecular genetics, molecular systematics, ontogeny, palaeobotany, palynology and micro- and macrosystematics.

Equipment

Sophisticated equipment should include, amongst others, a cibachrome copier, colour photocopier, up-to-date computer hardware and software (including flat bed scanner, CD-ROM and WORM drive), desktop publishing facilities, laminar flow bench plus associated micropropagation equipment (Fay & Muir 1990), state-of-the-art photographic studio, satellite positioning equipment, scanning electron microscope, state-of-the-art separation equipment, transmission electron microscope and X-ray microanalysis equipment.

Library

Extensive library with full-time librarians and associated state-of-the-art archives. Such libraries should contain all necessary books, journals, microfiche, pamphlets, maps and gazetteers. Book exchange and photocopy request

capabilities are also essential. There should also be a microfiche reader, CD-ROM reader, necessary computer facilities and a photocopy machine.

Collections

Extensive ancillary collections. These should include the following: art work, carpological collection, DNA samples (Adams *et al.* 1992), economic plant collection, germplasm or seed bank (Towill & Roos 1989; Hawkes 1990), illustrations, living collections, photographs and slides, plant genetic resources (Nagamine & Nakagahra 1989), spirit collections, voucher collections and wood collections. Serious consideration should also be given to collections of cryopreserved germ plasm (Sakai 1993) and cryoconservation (Villalobos & Abdelnour 1992).

Gardens

Associated botanical gardens with extensive greenhouse facilities. Staff should be adequate and well trained (Hamann 1990).

University affiliation

Centres of excellence should be affiliated to a nearby university that has a good botany department. Reciprocal arrangements should be made for lecturing and the availability of communal resources, especially were these relate to the training of post-graduate students.

Scientific collaboration

Staff should be encouraged to undertake collaborative work with researchers in other fields of science. For instance, the magnetic resonance imaging (Veres *et al.* 1993) of plant structures could lead to collaboration with radiology departments and staff at hospitals or at universities.

International image

Local centres of excellence need to develop a good international image. In order to acquire such an image they would need to produce research of an internationally acceptable standard. Staff should have international connections and be aware of front-line developments and major paradigm shifts occurring in botany and the biological sciences. If approached to referee papers for international journals, they should be encouraged by Management to do so. They should also be encouraged to participate in and attend relevant international conferences. Management should actively encourage contact with major overseas institutions such as the botanical gardens at Kew, Missouri, New York and many others.

Conferences

They must have the ability and resources to organize relevant national and international conferences and to host regional workshops and working groups. Staff should be encouraged to participate in and attend such conferences.

Overseas tenures

Exchange arrangements/tenures with overseas scientists and institutions should be organized. Centres should have funding and resources to accommodate a limited number of overseas post-doctoral researchers.

Computerization

They should have a sophisticated computer-based data capture, storage and retrieval system (Brown 1988). Such a system must be able to interface with other such systems around the world. Computers also have a role to play in conservation (Crovello 1977). At least one computer-trained botanist (ideally an entire data section as is found at the National Herbarium in Pretoria) is required.

Journals

They should have a full-time publications department capable of producing at least one in-house journal and congress proceedings. This department could interface with education/public relations.

Education

They should have an education and public relations department with full-time, specialist staff. This department must interface with both the media (printed, vocal and visual) and government (local, regional and national). It must have the ability to organize and deliver well presented, relevant talks and tours. Staff must be involved and help with outside education as well as social and economic upliftment programmes, especially where these relate to the environment and to biodiversity issues. Such a department must be able to produce the necessary pamphlets, booklets and videos in collaboration with the publications department.

Training

Facilities and staff should be able to provide training to its own staff and to staff of related organizations.

Economic integration

Full-time fund-raising staff are required. Such staff should also be involved with commercializing and marketing as many products of these centres of excel-

lence as possible. Such products include expertise and information, including electronic data.

Atmosphere of learning

Such centres of excellence need to develop a university or academic atmosphere rather than the present public service attitude many of them have. Staff should be encouraged to think innovatively and to use their initiative.

Management

Centres of excellence require properly trained, skilled managements with a forward vision. Such managements should be committed to across-the-board, nonbiased botanical research. They should also have some business acumen and the ability to run the centres and their staff in a professional manner.

SMALLER HERBARIA

Smaller herbaria also have a major role to play in southern Africa's future. Many are actively involved with botany departments teaching the next generation of graduate professionals, whether these be teachers, doctors or entrepreneurs. As such, these teaching herbaria should be seen as essential tools needed to uplift living standards on a regional basis and also to help bring a better and more prosperous life to the inhabitants of their region. Many of these smaller herbaria also connect with local and regional economies and are therefore important to a good financial base at the local level. Some of the smaller, older herbaria contain important historical collections or valuable type specimens.

Unfortunately, these smaller herbaria are threatened with the same negative forces affecting larger herbaria but are often less able to defend themselves adequately. Such herbaria need to draw up adequate mission statements and develop assertive management systems that can constructively petition controlling bodies for more money and support. They should also form support groups with other concerned parties if these are not presently available.

CONCLUSION

The extinction crisis is with us and it is our generation that will have to make a strong commitment (including financial) to an all-out effort to minimize the impact of human population growth on the botanical diversity of southern Africa (Ledger 1991; Hedberg & Hedberg 1992b). Unfortunately, too often, green issues are seen as obstacles to the economic empowerment so desperately needed to uplift the living standards of people in the subcontinent. Such perceptions must be changed, governments and industry need to be made aware that indigenous plants are a sustainable, money-generating resource that can be used to help build the economy of the region. Nonrenewable resources are relevant to short-term

economic survival, while sustainable resources (such as plant genetic resources) offer long-term economic growth and survival.

Herbaria have an important, almost central, part to play concerning the wise utilization and sustainable management of these genetic resources. Not only are herbaria 'arks of plant diversity' (that must be proportional in number and facilities to the richness of the flora of which they are custodians), but they are also an integral part of any complex economy relying on plant names and resources to help generate money and so raise living standards.

It is ironic that at this time in the earth's history when herbaria are most needed, the negative forces affecting their running and well-being are increasing to the point where many herbaria are unable to play any effective role in the society of which they are an integral part. Whether, in fact, southern African herbaria will be able to survive in the future and play a meaningful role for the countries of this subcontinent, depends upon their sound management and the continued emphasis on their usefulness and value to mankind.

Present-day leadership across the board must now be urged to play its part. Leaders must help build up the herbaria of southern Africa so that they are in a position to meet and find solutions to the challenges that face the subcontinent as it prepares to enter the 21st century.

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Botanical diversity: education, training facilities and human resources in southern Africa

R.D. WALMSLEY*, J.J. WALMSLEY** and A. ANATI***

* Foundation for Research Development, P.O. Box 2600, Pretoria, 0001 South Africa.
** Swan Consulting, P.O. Box 1122, Garsfontein, 0042 South Africa.
*** Ministry of Science and Technology, P.O. Box 18195, Jerusalem, 91181, Israel.

ABSTRACT

The wise management of any country's plant resources can be achieved only through the development of an understanding of their properties and values. This is turn demands an appropriate level of infrastructure for research, education and training. In this paper we discuss the countries of the southern African region with special reference to their university infrastructure. The *Science Citation* system was used to identify quality contributions to botanical knowledge, as well as research activities within each country. The region is currently ill-equipped to provide an adequate service backup for the wise management of its plant resources. South Africa is identified as the major scientific contributor to botanical knowledge in the region. It is advocated that, in the absence of initiatives from the political leadership, scientists themselves will have to take on the task of promoting and developing expertise in the region.

INTRODUCTION

Africa contains some of the most underdeveloped countries in the world (UNESCO 1991). Symptoms such as overpopulation, poverty, starvation, illiteracy, corruption, lack of human rights, violence, war, refugees, foreign debt, urbanization and vanishing resources are the realities with which every decision-maker must contend (Todaro 1990). The global economic system, with its dichotomy of a relatively rich Northern Hemisphere and a poor Southern Hemisphere, further adds to the perpetuation of these conditions. Recognizing these problems, and in an effort to reverse these negative trends, the United Nations established a World Commission on Environment and Development (WCED) in 1983. The Commission, whose findings and recommendations were published in a report entitled *Our common future*, provided a guide as to how the concept of sustainable development could lead to an improvement in the quality of life in all the countries of the world (WCED 1987). The problem of conserving living natural resources (species and ecosystems) was identified by the WCED as a major challenge facing the world.

In the Third World setting of Africa, botanical resources are of particular value to millions of subsistence-level people who make daily use of plant resources (Cunningham *et al.* 1992). However, there is evidence to indicate that sub-Saharan Africa is losing plant species about which little or nothing is known (Stuart *et al.* 1990). Countries such as Madagascar, Tanzania and South Africa have large numbers of endemic plants, yet land-use practices threaten the future of their unique flora and habitats. The database to support the management of plant species is limited and unevenly distributed, as is the human resource base that is needed to facilitate education and research on indigenous plants and their use.

Management of any resource requires appropriate training, education and research in order to develop the necessary expertise and experience from which wise decisions can be made. Policies that develop a country's human resources via academic institutions are therefore crucial to development. The importance allocated to a particular resource by a country is usually reflected by the academic infrastructure (institutions, personnel, students, etc.) that supports its management. Basic educational and research infrastructure provides a good indication of each country's ability to manage its resources wisely. This paper examines some countries within the southern African region, with the following objectives:

- to provide a comparative assessment of their ability to research and develop expertise for the conservation of botanical resources;
- to highlight strengths, weaknesses, opportunities and threats that prevail;
- to make recommendations for future activities which could lead to the strengthening of botanical expertise in the region.

EDUCATION AND TRAINING FACILITIES

Information on specific countries was obtained from a variety of sources, including Barnard (1992), Leistner & Esterhuysen (1988) and UNESCO (1987, 1991). Personal correspondence and direct communication with many institutions were also attempted. Because communication with some of the countries was found to be extremely difficult, the information presented has been restricted to macrotrends in university institutions and botanical publications. The debate over which countries should be included within the umbrella of 'southern Africa' is ongoing (Fair & Esterhuysen 1988). Inclusion depends on historic, cultural, political, economic and geographic perspectives. From a South African perspective, southern Africa consists of 10 countries: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Zambia, Zimbabwe and South Africa. However, from an African and international perspective, there is an economic and political alignment of certain countries (Tanzania, Zimbabwe, Zambia, Botswana and Malawi) to form the Southern African Development Community (SADC). For the purposes of this comparative paper we have included Tanzania, Madagascar and Mauritius (Table 1). This treatment should in no way be interpreted as a statement that other countries in Africa that share common botanical resources

are unimportant, or should be excluded from participation in future actions. Indeed, many of the facts and principles apply to most of sub-Saharan Africa.

All of the southern African countries have at least one university institution, with Madagascar, Malawi, South Africa, Zambia and Zimbabwe having more than one (Table 1). A recent survey on indigenous plant use research in sub-Saharan Africa (Anati *et al.* 1994) indicates that South Africa has at least 47 institutions involved in indigenous plant research, Zimbabwe has nine, Malawi and Mauritius have four and Zambia has three, while the rest of southern Africa has only one (Figure 1). South Africa, with 21 accredited universities, is therefore the most advanced in terms of its overall tertiary education system.

A similar pattern prevails with regard to the total number of university lecturing staff and students attending university. However, the status is better appreciated by normalizing the data to numbers of staff and students per 100 000 habitants and comparing the values of the southern African region with those of some countries in Europe, North and South America (Table 2). The extent of the disparity between the educational systems of the industrialized western countries and those of Africa is self-evident. For example, South Africa, with purportedly the best educational system in the subregion, has six times fewer students propor-

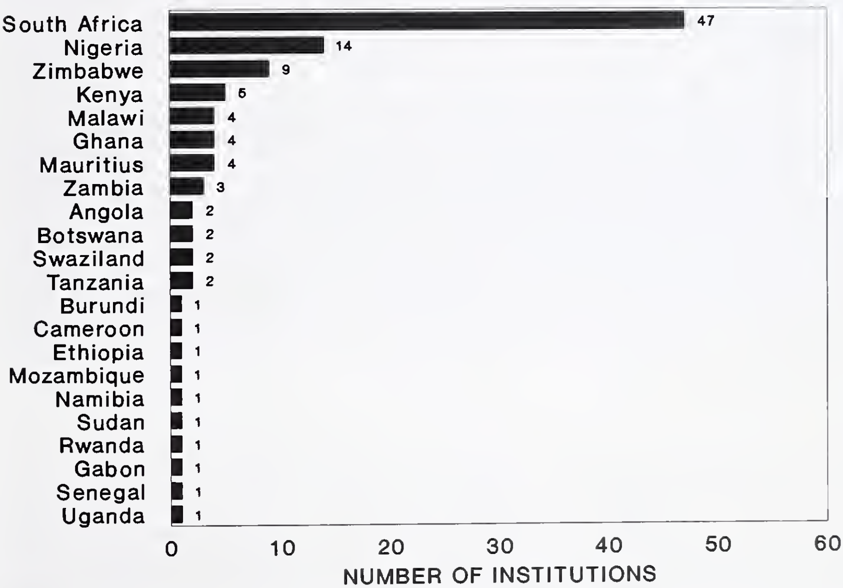

Figure 1.—Number of institutions that participated in the indigenous plant use survey for various countries.

TABLE 1.—Characteristics of some southern African countries—GNP and population data from WRI (1992)

	Angola	Botswana	Lesotho	Mauritius	Madagascar	Malawi	Mozambique	Namibia	South Africa	Swaziland	Tanzania	Zambia	Zimbabwe
Area, km^2	1 200 000	561 730	30 355	600 000	118 454	2 000	780 000	823 144	1 220 088	17 355	940 000	752 614	390 759
Population, millions, 1990	10.0	1.3	1.8	12.0	8.8	1.1	16.1	1.8	36.8	0.8	27.3	8.4	9.7
Gross National Product—US$, millions, 1989	6 010	1 105	816	2 543	1 475	2 068	1 193	1 540	86 029	683	3 079	3 060	6 076
Number of university institutions	1	1	1	3	2	1	1	1	21	1	1	2	3
Number of tertiary lecturing staff	293	250	295	960	407	382	368	164	14 090	183	847	996	2 308
Number of students in tertiary institutions	4 493	2 837	5 577	37 046	4 951	2 179	2 335	3 548	324 015	3 363	3 638	14 465	49 361
Number of university botany or biology* depts	1	1	1*	–	2*	1*	1	1	18	1*	–	1*	2*
Number of botany or biology* lecturing staff	3	5	4*	–	4*	4*	4	3	126	4*	–	4*	13*
Number of botany undergraduates	8	385	180	–	513	30	2	50	3 284	186	–	575	235
Number of postgraduate botany students	–	0	0	–	13	2	0	0	257	0	–	0	22
Number of plant species	5 000	2 000	1 700	11 000	5 500	900	5 000	3 159	20 300	2 715	11 000	4 600	4 200

– = data unavailable.

tionally than the USA, which has the highest number of the countries selected from the industrialized nations. Similarly, South Africa, which has the highest university staff factor of the southern African countries, has six times fewer teaching staff per 100 000 inhabitants than Germany (Table 2).

TABLE 2.—Number of university-level staff and students per 100 000 inhabitants—data from UNESCO (1991)

Country	University staff	University students
Angola	3	44
Botswana	21	236
Lesotho	14	324
Madagascar	8	308
Malawi	3	26
Mauritius	22	135
Mozambique	2	15
Namibia	9	197
South Africa	38	880
Swaziland	14	161
Tanzania	3	14
Zambia	5	74
Zimbabwe	6	92
Brazil	86	1 045
Canada	139	5 034
France	82	2 842
Germany	243	2 843
United Kingdom	60	1 954
United States of America	199	5 596

A comparison of southern Africa with the rest of sub-Saharan Africa in terms of indigenous plant research expertise gives an indication of the relative strengths of the various regions in terms of botanical expertise. Southern Africa (Angola, Zambia, Malawi, Mozambique, Zimbabwe, Namibia, Botswana, South Africa, Mauritius and Swaziland) employs 52% of the indigenous plant scientists of the sub-Saharan region (Figure 2), with South Africa employing 46% of all indigenous plant researchers.

Most of the universities in southern African countries have facilities for training botanists. At least six of the countries train students via the media of biology rather than botany, whereas the others have dedicated botany departments (information unavailable for Madagascar and Tanzania). Apart from South Africa, which has 16 botany departments and a total of at least 126 full-time botanical lecturing staff, the rest of the countries have extremely fragile and critically short academic teaching bases. For example, Angola and Namibia have only three members of lecturing staff to service the whole of their respective countries!

The status of undergraduate and postgraduate students involved in botanical training is also of concern. Numbers of undergraduates undertaking botanical study are extremely low, particularly in Angola and Mozambique, which have fewer than 10 undergraduates. Postgraduate students are almost nonexistent entities in Angola, Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zambia. Figures in Table 1 represent the botanical postgraduates registered in the respective countries, but there might be students who have registered at universities in other countries.

RESEARCH PUBLICATIONS

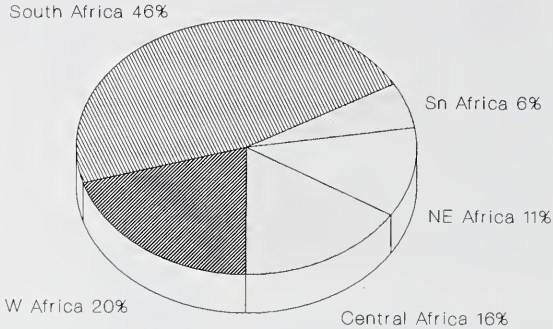

Figure 2.—Proportion of scientists in the indigenous plant use database from different sub-Saharan regions. Sn Africa = southern African countries other than South Africa; NE Africa = Ethiopia and Sudan; Central Africa = Kenya, Uganda, Rwanda, Burundi, and Tanzania; W Africa = Senegal, Ghana, Nigeria, Cameroon, Gabon. Source: Anati *et al.* (1994).

Refereed and accredited publications also provide a useful measure of the output, productivity and quality of research in a region. A survey of botanical literature for 1992 recorded by the *Science Citation Index* system (Institute for Scientific Information 1992) reveals some interesting comparative statistics (Table 3). Africa produced only 2.41% of the world's accredited research articles in 1992, with southern Africa contributing 48% of these, and South Africa making up 84% of the southern African contribution. More detailed investigation revealed that only four of the articles produced in the southern African region outside South Africa were senior-authored by local scientists. The remainder were authored by visiting scientists from European countries who had used the southern African university as a temporary base.

Special mention needs to be made of the South African situation. By comparison with the other southern African countries, South Africa appears to be secure in its education system. Numerically, it contributes to more than 80% of the region's activity measured in terms of GNP, botanical expertise, publications, etc. However, more detailed studies of the botanical expertise base at universities have revealed that this advantage is superficial (Walmsley 1991, 1992). Walmsley (1992) has shown that research funding and activity is unevenly distributed between the universities and there is a situation in which historically 'white' universities have enormous competitive advantages in terms of staff, infrastructure, research funding and students. Some of the historically white universities have the ability and potential to compete with the best in the world. This is illustrated by the fact that three universities (Natal, Orange Free State and Pretoria) generated more than 50% of the botanical *Science Citation* articles for

TABLE 3.—Research articles on botany recorded in 1992 *Science Citation Index* system

	Number of articles	Percentage
World	10 593	100.00
Africa	256	2.41
Southern Africa	125	1.18
South Africa	105	0.99

1992. In contrast, several of the country's historically 'black' universities are in no better position than universities in other southern African countries. Throughout southern Africa, there are few black scientists involved in botanical research.

GENERAL DISCUSSION

The botanical education, training facilities and human resources of southern Africa are largely a reflection of the region's social, economic and political structure. On the available evidence, the conclusion can be made that the region is currently ill-equipped to provide an adequate service backup (education, training, information and research) for the wise management of the region's plant resources. The causal factors behind the current state of affairs are wide-ranging. African countries have suffered from numerous inhibitory forces, all of which have marginalized the continent and its constituent countries. Leistner (1993) considers these to include:

- their colonial context;
- poor economic performance;
- war and destabilization;
- apartheid and ethnicity;
- high population growth;
- poor educational infrastructure;
- inefficient land use and food production;
- unemployment;
- foreign debt;
- corrupt, undemocratic and ill-informed politicians.

Most African countries lack an effectively operating science system to provide a vision, finances, personnel and scientific services with the ability to transfer technological information to their developing and needy populations. As early as the mid-1980s UNESCO (1987) recommended that countries of southern Africa needed to:

- create national science policy-making bodies;
- develop human resources;
- develop financial resources;
- popularize science;
- secure regional cooperation.

From the evidence on botanical science, little progress appears to have been made on these fronts during the last decade. One is left with the question: what can be done to uplift botanical research and education in the southern African countries? It is beyond the scope of this paper to discuss and present remedies to the tertiary education problems of southern African countries. However, a solution to the botany problem cannot be made without a complete review and

overhaul of the tertiary and secondary education activity in each of the respective countries. Furthermore, the discipline of botany alone cannot solve the problem of species conservation as advocated by the WCED (1987). Other supportive disciplines such as zoology, chemistry, geography, agriculture, pharmacy, sociology and economics are also required.

The WCED (1987) concludes that species conservation is tied to development in that it requires training, education, research and human resources. Definite policies need to be developed for each country which take relevant social, political and technical considerations into account, ultimately with the goal of upgrading science in each of the southern African countries. Leistner (1993) cites human shortcomings rooted in historical circumstances and sociocultural constraints as the major barrier to economic development in African countries. Tindimubona (1993) believes that Africa requires a scientific cultural adjustment programme which transforms traditional African approaches into a more globally competitive one. The development of appropriate policies in southern African countries will require considerable political leadership in order to overcome the inertia of their existing systems.

The current political leaders of southern African countries have demonstrated that they either lack the will or foresight to create appropriate scientific infrastructures that can assist with development. It is therefore advocated that scientists themselves need to play a more dominant role in (1) lobbying for improvements in their respective countries, and (2) creating appropriate networks and programmes to support the lobbying action. At present there are numerous opportunities for botanists (and scientists from other disciplines) to contribute towards achieving such goals. These include, amongst others:

- International treaties emanating from the 1992 United Nations Conference on Environment and Development. In particular those on biodiversity, forestry and global climate change hold promise.
- International research programmes such as the International Geosphere Biosphere Programme (IGBP), activities of SCOPE, IUBS and the IUCN.
- The survey of indigenous plant use expertise in sub-Saharan Africa (Anati *et al.* 1994) has shown a wealth of interest from all countries in the region. The development of a network of institutes and scientists involved in indigenous plant use research will facilitate the process.
- Capitalizing on the strengths of the South African botanical educational system by promoting joint and cooperative regional ventures between institutions.
- Making use of international agencies such as UNESCO, UNEP and the IUCN to facilitate programmes and projects in Africa.

More than 40 years ago Sir Basil Schonland, in an address to the British Royal Society (Schonland 1948), stated: 'The flora and fauna, the geology, ethnology and the climate of Africa are not divided by nature. If the continent of Africa is to

develop as it should, there is a need for closely cooperative regional research into its problems and South Africa is ready to give such cooperation its fullest support.' This address led to the formation of a Scientific Council for Africa, which promoted scientific interaction between sub-Saharan countries in the 1950s. The operations of this Council ceased in the early 1960s. Southern Africa is perhaps faced with the situation of reinventing the wheel, in that the vision of Schonland needs to be resurrected in the new and dynamic southern Africa of the 1990s. It is hoped that botanists will take the initiative and be in the front ranks of the networking system to place this vision on the African science agenda once again.

CONCLUSIONS

- Most countries of southern Africa have inadequate science policies as reflected by the weak structure of their university education systems.
- All countries of the southern African region have facilities for training botanists. With the exception of South Africa, they have extremely fragile and critically short academic teaching bases.
- Postgraduate botany study is almost nonexistent in more than half of the countries of the region. Research activity, as measured by publication output, is low—with southern Africa contributing only 1.18% of the world literature.
- The region is currently ill-equipped to provide an adequate service backup for the wise management of the region's plant resources.
- Action should be taken to capitalize on the strengths of the South African education system by forging cooperative ventures between scientists of all countries. The development of a regional indigenous plant use network is advocated.

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A proposed index of biodiversity

H.P. LINDER

Department of Botany, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

ABSTRACT

Biodiversity is a rather vague term that describes the degree of variation in the biota of a particular area. This variation may be taxonomic (i.e. the number of species, or genera, or families), morphological (the range of morphological structure), phylogenetic (the patristic distance between species on a cladogram, or some assessment of the phylogenetic distance between species), functional (the range of ecologically functional attributes of the biota), etc. Here I develop an index of biodiversity which combines as many of these components of biodiversity as possible, and yet is easy to apply from readily accessible data. This index is most useful for comparing the biodiversity of different areas. The first step in the calculation of this index is to develop a measure of the rate of increase in functional diversity as more taxa at the same rank are added (e.g. species, or genera, or families), for different ranks. This measure is then used to deweight the floristic lists for the areas to be compared, in order to offset imbalances caused by very speciose genera or families. This therefore measures the contribution of the entire biota (if so wished) and not only of a few taxonomic groups which are well enough known. Examples are presented to illustrate the results of applying the method.

INTRODUCTION

Although conservation decisions are usually the result of political and ethical considerations, there is a scientific argument for conservation, and a scientific aim for conservation: and that is to minimize the loss of biodiversity (Walker 1993; Margules *et al.* 1988). However, the concept of biodiversity is complex, and contains several elements which are difficult to quantify. Erwin (1991) defined biodiversity as ‘species richness, that is the number of species, plus the richness of activity each species undergoes during its existence through events in the life of its members, plus the nonphenotypic expression of its genome’.

The practical problems of prioritising conservation areas require a wide range of scientific approaches, as there are many scientific criteria that are important in conservation management decisions. These include genetic decisions, like the minimal viable sizes of populations (Lesica & Allendorf 1992), ecological management decisions, like the threats of invasive weeds, disturbance from environmental pollutants, like fertilizers and herbicides, as well as taxonomic decisions, like maximizing the conserved pool of biodiversity. In the case of the latter, it is impossible to make a complete listing of the forms of life found at any particular

site. Therefore we have to work with 'indicators' of biodiversity. Various biological and geomorphological attributes have been used as indicators of biodiversity. Nilsson (1986), Lesica (1993) and Keel *et al.* (1993) used the diversity of landforms and vegetation types as indicators, while Kirkpatrick (1983) and Rebelo & Siegfried (1992) suggested using striking or rare plants. A portion of the biota in an area (such as the birds, or the angiosperms) is frequently used.

EVOLUTION OF BIODIVERSITY

We can analyse the origins and maintenance of biodiversity from two approaches: phylogenetic and geographical.

Phylogenetic diversification

There are two aspects to the evolution of the diversity in a lineage through time:

The first aspect of the diversification of a lineage is the accumulation of species diversity through time. This is as yet poorly understood, and only correlates with change in species composition if the confounding effects of pseudoextinction are removed. Thus we have a relationship between speciation and extinction. If speciation is assumed to follow the dumb-bell model, then extinction is a prerequisite for speciation in the same lineage, and therefore an increase in speciation rate results in an increase in extinction rate (Archibald 1993). But if speciation is assumed to be peripheral, then the ancestral taxon is not immediately replaced by the descendant species, thus leaving persistent relicts and introducing a lag between speciation and extinction rates. The actual patterns of speciation in the world's biota are poorly known, and can only be resolved once students of phylogeny start treating species in an evolutionary dynamic rather than in a typological manner.

Erwin (1991) suggests that species clusters, which may be detected from the topology of a cladogram of the relevant group, represent actively evolving lineages, compared to basal, isolated species, which probably indicate lineages in which evolution is proceeding relatively slowly. He argues that it may be more important to conserve the 'active' species, rather than the 'basal' species.

The second aspect is the accumulation of functional diversity through time. This can be plotted onto a cladogram, and by optimizing the various structures and their functions to the nodes, we can reconstruct the structure and function of the putative ancestors of the living forms. Functional diversity almost certainly does not aggregate continuously; its evolution is subject to morphological and genetic constraints (Linder 1991).

Regional diversification

On a regional or geographical basis biodiversity can be understood to be a collection (usually) of partial clades, and the explanation of regional diversity may

either be in ecological terms (coexistence of many different species) or in historical terms (historical events, such as glaciations). Both these factors are frequently invoked as explanations of patterns of diversity (e.g. Cowling *et al.* 1992). The balance between the number of species, number of higher taxa, and different life-forms can be used to generate hypotheses about the contribution of history and ecology to the current diversity patterns (e.g. Linder *et al.* 1992). But this does mean that there is no simple model to work from, as each region would have a unique history, and this may be why biodiversity on a regional basis is so difficult to understand.

It would simplify conservation arguments if all species could be assumed to contribute equally to a total estimate of biodiversity, either of a lineage or of an area. But it is immediately apparent that the loss of one species of *Erica* out of a genus of more than 800 species would not deplete the world's biodiversity as much as would the loss of *Welwitschia mirabilis*, the only species of the Welwitschiales. There are numerous ways in which species can be weighted for conservation, but it would be useful to be able to determine a single 'calculus of biodiversity' (May 1990).

CONSERVATION AND BIODIVERSITY

There are several interwoven strands in the assessment of the contribution of each species to the biodiversity of an area. Although I discuss them separately below, they should be implemented simultaneously when making any assessments.

Complementarity concept: this is based on the iterative method devised by Kirkpatrick (1983) and elaborated by Margules *et al.* (1988) and Rebelo & Siegfried (1992). No matter how highly a species is regarded, as soon as it is adequately conserved, it is no longer used as an argument to conserve another area. This prevents a few highly regarded species from controlling all conservation decisions, while some not-so-highly regarded species are not conserved at all. Thus a series of reserves are placed to maximize the number of species conserved. As soon as species are found in one reserve, they are removed from the list of desirable-to-conserve species. This requires an adequate taxonomy at species level and fairly complete checklists for reserves or proposed reserves.

Weighting of species: there has probably always been a selection of species for conservation, whether it be red deer in Richmond Park, mountain zebra in the Mountain Zebra Park, or some species of *Mimetes*. There are a number of explicit criteria on which to base weightings. One of the earliest used is rarity (Kirkpatrick 1983). Recently there have been various arguments using ecologically important species (Walker 1993) or keystone species (Bond 1993). I wish to explore more direct indicators of biodiversity, and these can roughly be classified into regional and phylogenetic measures:

On a regional basis, the following approaches exist:

1. The number of different species—either as a simple species list, or as various measures of alpha, beta or gamma diversity; this implies that all species are weighted equally.
2. The number of different higher taxa—also referred to as the variation in basic design or as the disparity in the group.
3. The number of functional types, or basic growth forms—this would be somewhat equivalent to guilds. Cousins (1991) and Walker (1993) also use the number of species in each guild.

The determination of biodiversity within clades tends to take into account the following patterns:

1. The number of species in each branch of the clade.
2. Some estimate of the degree of difference between the species. There are several measures. Faith (1992a, b) suggests using the patristic distance between species to measure their differences, his 'Phylogenetic Distance'. Vane-Wright *et al.* (1991) and Williams *et al.* (1991) proposed a set of measures that include the number of nodes between taxa, the number of species in a clade, etc. The intention of these measures is to ensure that representatives of each clade are conserved, while Faith's approach is more to maximize the diversity of the conserved taxa.
3. The genetic diversity in clades (Crozier 1992; Rojas 1992). The previous measures treat species in a typological sense: a species contains no internal variation, and has no evolutionary potential. Rojas (1992) suggests that this could lead to misjudgements, and that in many cases it would be more sensible to deal with sets of populations, rather than with species.

TAXONOMIC AND FUNCTIONAL DIVERSITY

These criteria are based purely on taxonomic or phylogenetic data. But biodiversity can also apply to a diversity of processes within a clade or an area: dispersal mechanisms, pollination syndromes, predator-defence systems, production systems—what Erwin (1991) terms 'richness of activity each species undergoes'. This is quite distinct from establishing a classification of 'guilds' and assigning species to these guilds. I would prefer to argue that we need to maintain the greatest diversity of functions within the system, thus avoiding having to make classifications of guilds. Thus we would wish to retain as many different pollination syndromes, antiherbivory strategies, etc. The assumption is that the greater the diversity of these functions, the larger the number of 'attendant' species that can be conserved, and consequently, the better the biodiversity figure would be in estimating the total biodiversity of the system.

A PROPOSED INDEX OF BIODIVERSITY

There are two approaches to estimating this functional diversity in the system. Phylogeny as a predictive system should give an indication of the functional diversity contained within a clade, and this logic underlies the logic of the 'calculus of biodiversity' developed by Vane-Wright, Williams & Humphries (May 1990). Faith (1992a, b), by using patristic distances, captures this diversity more directly. Linder & Midgley (1994) developed a system for directly estimating the functional heterogeneity that results from increasing the taxonomic diversity at each rank.

The protocol for calculating this is as follows:

1. Select a set of functional attributes (i.e. pollination system, seed dispersal system, rooting strategy, growth form, fire response type, etc.).
2. Within a genus, score up each species for its functional attributes.
3. Randomly select one species, record its functional attributes.
4. Randomly select a second species, add it to the first species, and calculate the increase in the functional diversity.
5. Randomly select a third species, add its functional attributes to those of the first two species, and record the increase in functional diversity.
6. Continue until all species have been added.
7. Graph the results indicating how rapidly the range of functional attributes increases.
8. Calculate the rate at which the functional attributes increases between genera, by randomly selecting one species from each genus in a family, and repeating the above procedure.
9. Randomly select one species from each family to calculate the rate at which functional diversity increases between families.

This approach avoids the problems of calculating patristic distances or developing estimates of phylogenetic relatedness for large floras, by using the existing taxonomic ranking system. However, this assumes that taxonomic ranks in different groups of plants are comparable. Supraspecific taxa, if delimited as monophyletic groups, are arbitrary as to rank, but not as to content. However, since supraspecific taxa are usually delimited at positions of maximal morphological change (usually of the longest patristic distances), there is a constancy in the rank at which these taxa are recognized, and taxa tend to be constant in terms of biology (Linder & Kurzweil 1994). Therefore, this type of extrapolation is probably valid.

Linder & Midgley (1994) explain the method, but did not do enough replicates to show that this method actually results in statistically significant differences in the rates at which functional diversity is accumulated in the various taxonomic ranks. Here I assume that this method will, when more cases are examined, return

statistically significant results, and consequently can be used to deweight the contributions from different taxonomic ranks by the rates at which they contribute to the functional diversity of the system. Ideally, these deweightings should be calculated from several different areas, or if two areas are to be compared, from those two areas.

To calculate this diversity index, the contributions from the number of families, number of genera and number of species are deweighted by the rate at which the addition of new members at that rank contributes towards the functional diversity of the system. The deweighted values are then summed, and this value is termed the 'Diversity Index' or DI.

To test the method, two sets of analyses were performed on floras of various sizes from southern Africa.

1. Comparison of several large areas (Figure 1):

    a. Cape of Good Hope Reserve (CGH), Cape Peninsula, Stellenbosch and southern Drakensberg. The Drakensberg is not as diverse as the Cape flora regions. It is interesting that although the CGH is more speciose than Stellenbosch, it has a lower Diversity Index. It also has an almost pure 'fynbos' flora, while the Stellenbosch area contains several different soil types, and extensive forest patches.

    b. The Cape Floristic Region (CFR, Goldblatt 1978) vs Natal, with the CFR with almost twice as many species, but with the Diversity Index being only a third more. Thus we see the DI reducing the impact of high species numbers. Both areas contain a diversity of vegetation types.

    c. Kalahari Gemsbok Park (KGP), which has a very low diversity and biodiversity. This sort of problem was already detected by Nilsson (1986) and Lesica (1993), who showed that an exclusive emphasis on biodiversity would lead to the missing of peculiar habitats and environments with a low species diversity.

2. Comparison of several small areas (Figure 2):

    a. Cape Point Nature Reserve and the Roodeplaat Dam Nature Reserve have virtually the same number of genera and families, but the former is very much more species-rich, resulting in a somewhat higher Diversity Index value.

    b. This is in stark contrast to the comparison between the Nieuwoudtville Nature Reserve and Signal Hill. The much higher Diversity Index of Signal Hill is driven by the higher numbers of genera and families, relative to Nieuwoudtville (which is heavily dominated by the Asteraceae and Mesembryanthemaceae).

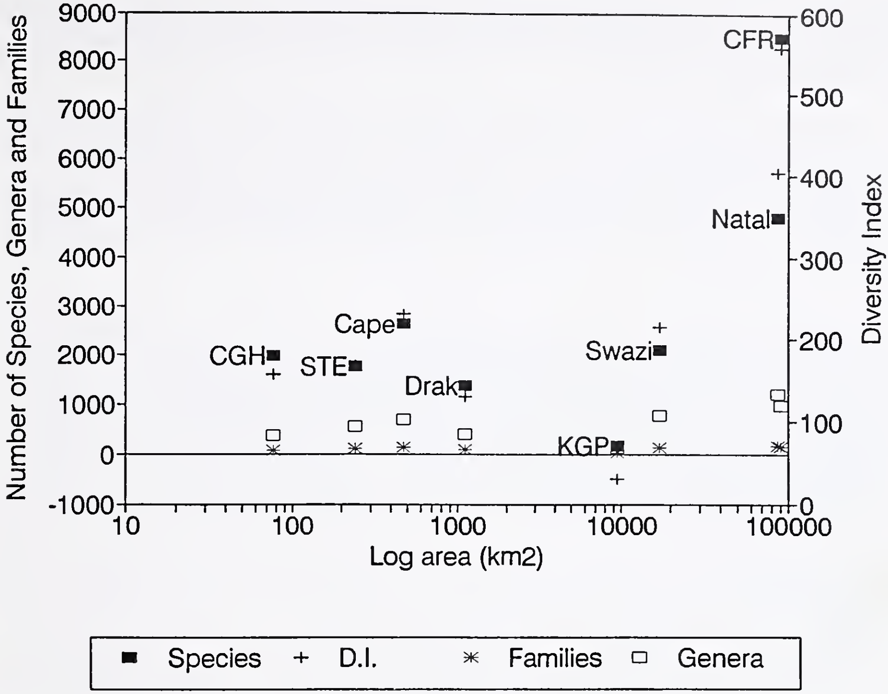

Figure 1.—Relationship between numbers of species, genera, families, the Diversity Index, from relatively large areas. Basic data from Taylor (1984); Buys *et al.* (1991); Bond & Goldblatt (1984); Hilliard & Burtt (1987); Adamson & Salter (1950); Compton (1976); Ross (1972); Leistner (1959).

DISCUSSION

Conservation is directed at maintaining the maximal biodiversity. Some general guidelines can be suggested to achieve this goal, but it would appear that there is no single criterion by which reserves can be selected or a rule by which they can be managed. I would suggest the following guidelines:

The reserve must ultimately be functional. It serves no purpose to conserve an area, no matter how diverse it is, if the species cannot reproduce, or if the area cannot be protected from pollution or biological invasion. These are primarily ecological questions which need to be taken seriously. We need to know what conditions are required for the conserved ecosystem to continue to function in both ecological and evolutionary time.

The most obvious step in maximizing the biodiversity conserved by a set of reserves is to employ some complementarity criterion. But the implementation of any complimentarity analysis depends on decisions on how to rank the species.

For any practical analysis to emerge, we need ranking methods that are feasible with our existing knowledge, which probably only includes a checklist for the reserve or putative reserve.

Ranking species equally, while the easiest method, has obvious flaws. Using phylogenetic or patristic distance ranking criteria requires a knowledge base quite beyond what is currently possible. The Diversity Index provides the easiest quick method for correcting for differences in the ratio of species to genera or families, based on the functional attributes of the species, rather than their taxonomic attributes.

However, care has to be taken with the implementation of 'biodiversity indices'. There are many other criteria for testing biodiversity in its broadest sense, and it may not be sensible to compare the Kalahari Gemsbok National Park with the Cape of Good Hope Reserve. For sensible decisions, biodiversity indices may make sense only if used within general vegetation types [e.g. a 'biome' in the South African context (Rutherford & Westfall 1994), or a phytochorion in tropical Africa (sensu White 1983)]. It is rather pointless to compare the diversity of the Cape of

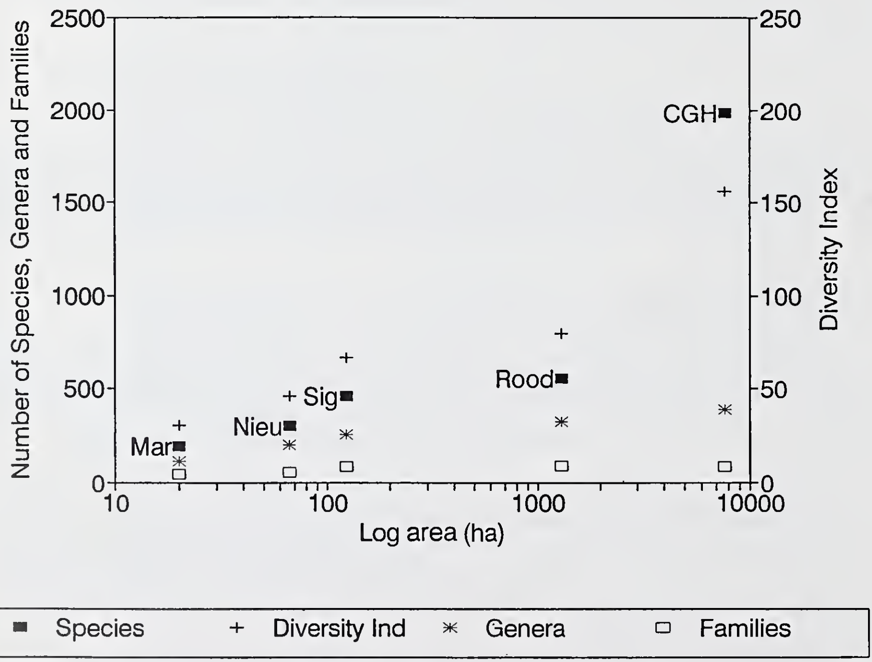

Figure 2.—Relationship between numbers of species, genera and families, the Diversity Index, from relatively small areas. Basic data from Haynes (1978); Snijman & Perry (1987); Joubert & Moll (1992); Van Rooyen (1983).

Good Hope Nature Reserve with that of the Kalahari Gemsbok National Park, but a comparison between the Cape of Good Hope Reserve and the Stellenbosch area would be valid.

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A preliminary investigation into the use of RAPD to assess the genetic diversity of a threatened African tree species: *Prunus africana*

N.P. BARKER*, A.B. CUNNINGHAM**, C. MORROW*** and E.H. HARLEY***

* Department of Botany, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.
** WWF/UNESCO/KEW People and Plants Initiative, 84 Watkins Street, White Gum Valley, 6162, Western Australia.
*** Department of Chemical Pathology, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

ABSTRACT

For over 20 years, bark or bark extract from the Afromontane forest trees *Prunus africana* (Hook. f.) Kalkman (Rosaceae) has been commercially harvested and exported to Europe for preparation of capsules to treat prostatitis. All of this harvesting is from wild populations and with the large volumes involved, concern has been expressed about the effects this has on Afromontane forest habitat as well as genetic conservation of isolated populations on montane 'islands' of Central, East and southern Africa. In this study we assess the genetic variation between five populations of *Prunus africana* using RAPD (Random Amplified Polymorphic DNA) methods. The results have implications for conservation and forestry policy for this species, showing distinct differences between isolated populations from Uganda, Cameroon and South Africa, but not between more closely situated montane islands.

INTRODUCTION

By contrast with most cases of pharmaceuticals developed from plants, where discovery of novel bioactive compounds is followed by synthesis, this has not applied to *Prunus africana* (formerly *Pygeum africanum*). In this case, *Prunus africana* bark extracts containing several natural compounds rather than a single active ingredient, are used to prepare capsules used to treat prostatitis. Although some forestry trials have been implemented, cultivated supply sources for commercial harvesting have not been developed. As a result, the entire world demand (currently about 4 000 tonnes/year) for *P. africana* bark is focused on wild populations.

This has serious implications for Afromontane forest habitat in several source countries, particularly Cameroon, Zaïre and Madagascar and, to a lesser extent, Uganda and Kenya. There are several reasons for this. First, the Afromontane

centre of endemism with its high proportion of endemic plants, mammals and birds is a focus of international conservation effort. Destructive harvesting of *P. africana* trees increases canopy-gap density, affecting forest structure and reducing food sources for several endemic bird and primate species. Second, Afromontane forests, which are generally small and isolated 'islands', are increasingly being separated by agricultural clearing. Destructive bark harvesting and die-off of reproductively mature *P. africana* trees add to this isolation and presumably reduce genetic interchange between increasingly isolated populations. Despite efforts at sustainable bark harvesting from wild populations, this is the exception rather than the rule and felling or total debarking of trees is taking place in forests of northwestern Cameroon, Uganda, Zaïre and Madagascar. In Cameroon for example, an average of 1 923 tonnes of bark per year was processed over a six-year period (1986–1991). This implies that bark is taken from approximately 35 000 trees annually (Cunningham & Mbenkum 1993).

In addition, the genus *Prunus* has been recognised by the IBPGR (International Board for Plant Genetic Resources) as a priority for both *in situ* and *ex situ* conservation due to the economic importance of fruit crops (plums, almonds, cherries, peaches and apricots) in this genus. However, before any decisions about habitat and population management can be taken, and if *ex situ* conservation is to be attempted, then an understanding of the genetic diversity of the species is needed.

Several methods have been used in the past to assess infraspecific genetic diversity. These include morphometric analysis of variation, isozyme electrophoresis and DNA fingerprinting using probes of hypervariable repeat regions (noncoding) of the nuclear genome. However, many problems make these methods inapplicable for conservationists. Morphometric analysis of variation can be time consuming. It is sometimes difficult to find sufficient variation for effective analysis, and variation may be dependent on factors such as the organs sampled (e.g. leaves vs. flowers), the time of sampling (seasonal variation may be important), age of the specimen etc. In addition, the genetic factors controlling morphology are totally unknown. Isozyme electrophoresis has the advantage of dealing with known genes, but it often needs material to be collected in a very specific manner (e.g. stored in liquid nitrogen) and subjected to special conditions (e.g. anaerobic germination of seeds). Although often used at the population level, isozyme studies can occasionally fail to detect variation (e.g. Crawford *et al.* 1993). Conventional DNA fingerprinting methods do not require complicated collection methods and equipment, but do require substantial amounts of DNA, and therefore raw material. If one is dealing with a small plant, such as an orchid, the sample required may mean that one or more plants may need to be sacrificed, a serious problem if the species is already under threat. In addition, the number of probes available for use in fingerprinting is limited, and most have been designed for use in mammalian systems. Therefore they may prove unsuitable for use in plant studies.

This paper serves to present a new DNA-based fingerprinting method that, to a large extent, overcomes these problems and is applicable to conservation studies. This method is known by the acronym of RAPD (Random Amplified Polymorphic DNA). It makes use of the Polymerase Chain Reaction (PCR), a technique used to amplify minute amounts of DNA (White *et al.* 1989). The modification of PCR to provide a genetic fingerprinting technique was first described by Williams *et al.* (1990) and Welsh & McClelland (1990, 1991). Subsequently this method has been successfully used to, among other things, prove hybrid ancestry (Crawford *et al.* 1993; Welsh *et al.* 1991). It has also been used to identify cultivars (Weining & Langridge 1991), analyse breeding systems and reproductive biology (Fritsch & Rieseberg 1992; Philbrick 1993), search for additional genotypes in wild populations of cultivated species (Wilde *et al.* 1992; Russell *et al.* 1993) and to assess genetic diversity (Brauner *et al.* 1992; Dawson *et al.* 1993). Intensive RAPD studies have also been used to link traits such as disease or drought resistance to ‘loci’ amplified by the RAPD PCR (Paran *et al.* 1991).

The RAPD method is applied here to assess the genetic diversity of five populations of *Prunus africana*. It is hoped that this example will demonstrate the potential that this method has for conservationists and conservation issues, and that dialogue between conservationists and molecular biologists can be encouraged.

The major advantage of this method above isozyme electrophoresis is that it is more sensitive and therefore can detect variation in situations where isozymes do not (Brauner *et al.* 1992). It therefore has a greater probability of detecting variation within and between populations. Other advantages of this method over the others mentioned above include the requirement for minute quantities of DNA (nondestructive sampling), it is also quick and cheap, it requires low-level training of staff, and the almost infinite diversity of 10-mer oligonucleotide primers means that many diverse ‘fingerprints’ may be obtained. Disadvantages of the technique are that (at present) it is impossible to estimate levels of homo- and heterozygosity, and that the method, unless stringently controlled, may not be repeatable. However, the latter problem may be overcome by taking a few precautions which include sampling only young, undiseased tissue, extracting DNA from a relatively uniform quantity of leaf tissue from each specimen and the optimization of the reaction conditions prior to full-scale sampling. This latter stage requires control over aspects such as the reaction volumes, the cooling and heating rates, the starting concentration of DNA and the make and batch of polymerase enzyme.

DNA extraction techniques are generally simple, and require relatively easily obtainable chemicals. The laboratory equipment needed is (unless exceptional extraction problems arise) also relatively uncomplicated, and includes a benchtop centrifuge, routine electrophoresis equipment and ultraviolet visualization devices. The item of equipment central to the entire method is the thermal cycler, or PCR machine. All this equipment, as well as much expertise, is likely to be

found in existing laboratories in university biochemistry or microbiology departments, or hospital laboratories.

Although developing nations may not possess some or all this equipment, centres using this and related DNA techniques already exist in Kenya, Zimbabwe and South Africa. The creation of additional centres ought to be encouraged. International cooperative programmes should make it possible for conservationists in any nation to play a role in collaborative research of this nature, even though access to the relevant equipment in their own country is limited. Assuming that such equipment is available or that collaborative programmes can be set up, the cost of the method, on a per sample basis, is equitable to the cost of many of the other methods used in the past; possibly even lower. Final costs are dependent on the nature of the organisms, as DNA extraction in some species may prove more difficult than in others.

METHODS

Sampling

Trees from several populations of *Prunus africana* were collected from populations in Cameroon and Uganda by one of us (ABC). Additional sampling of the southernmost population of *P. africana* (Geldenhuys 1981) was carried out by NPB and CM. Material for DNA extraction comprised a few leaves of each tree that were dried over silica gel as described by Chase & Hills (1991).

From each of the five populations studied, five specimens were chosen—thus a total of 25 plants were sampled. Three of these populations were chosen for their geographic isolation (South Africa, Uganda and Mt Cameroon). An additional two populations from the Mt Cameroon region were included, to serve as a test of the efficiency of the method at distinguishing geographically close populations. Such populations have the potential to interbreed, and are therefore expected to have greater genetic similarity to each other than to the distant populations. A total of five populations were sampled, demarcated here as 'B' (South Africa), 'J', 'L' and 'M' (three populations from Cameroon) and 'R' (Uganda).

DNA extraction and amplification

DNA was extracted using the hot CTAB method described by Doyle & Doyle (1987), and the DNA concentration of each sample was determined fluorimetrically using a Hoeffer TKO 100 fluorimeter. RAPD primers were obtained from the Oligonucleotide Synthesis Laboratory, Nucleic Acid-Protein Service Unit, University of British Columbia. Preliminary RAPD-PCR was carried out on three randomly chosen specimens in order to optimize the magnesium (Mg) ion concentration for each of the chosen primers and the templates (i.e. specimens of *P. africana*). In all cases the starting quantity of template DNA was standardized at 50 ng. One unit of enzyme was used per reaction tube. In all cases the enzyme used was Stratagene (TM) Taq Polymerase. Once the optimum Mg ion concentration was

determined for each primer, all samples were amplified at the optimum conditions. A total of seven primers were used on all five populations. These primers are all from the set '100/1'. The numbers and sequences of each primer are as follows:

Primer 1	=	CCTGGGCTTC
Primer 5	=	CCTGGGTTCC
Primer 15	=	CCTGGGTTTG
Primer 25	=	ACAGGGCTCA
Primer 28	=	CCGGCCTTAA
Primer 75	=	GAGGTCCAGA
Primer 100	=	ATCGGGTCCG

The total reaction volume for each PCR reaction was 50 μl, and the thermal cycling conditions were set at 40 cycles at 94°C (15 sec), 40°C (15 sec) and 72°C (1 min). All amplifications were carried out using a Techne PHC 2 thermal cycler. This machine was linked to a Techne pump and chiller bath unit (PC 5 and CH 5 respectively). This pump and chiller bath provided a source of coolant to the thermal cycler that was at a constant temperature. The cooling phase of the amplification cycle was thus independent of ambient conditions. By these means, one possible source of variation in the amplification process was removed.

In order to visualize the amplified DNA bands, a small amount of radiolabelled dCTP was included in the PCR cocktail. The amplified DNA thus contained some of the radiolabelled nucleotide, allowing autoradiographic visualization. This method is not commonly used in RAPD studies, as visualization of amplified DNA is commonly carried out using Ethidium bromide, which, in the presence of DNA, fluoresces under ultraviolet light. These bands can then be photographed using suitable film and filters. However, because of the large size of the gel (running 25 samples side by side), it was found that the photographic system used to record Ethidium-stained gels was unable to produce photographs of suitable resolution, and this method was used only in the initial magnesium optimization phase of the study. A photograph of a typical autoradiograph is shown in Figure 1.

The PCR products were separated by electrophoresis on a 25 × 20 cm, 1.3% agarose gel in standard TAE (Tris-Acetic acid-EDTA) buffer. Bromophenol blue was used as a marker dye, and was allowed to run two thirds the length of the gel before the gels were then vacuum dried onto chromatography paper. The dried gel was placed in an autoradiograph cassette with X-ray film, which was exposed for 24–48 hours before being developed.

Analytical methods

For the purposes of this report, an uncomplicated analytical approach has been adopted. The bands observed on the autoradiographs were coded into a table, representing the data in a presence-absence format (i.e. 0 and 1 data). The scoring of bands is a subjective operation and a question of individual judgement, and in addition factors such as exposure time of films or autorads can affect the interpretation and presence/absence of faint and dark bands. For this reason, and

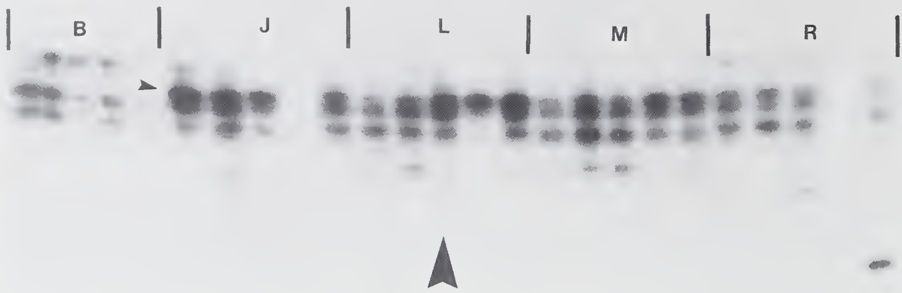

Figure 1.—A photograph of an autoradiograph showing the separation of the RAPD PCR products of 23 specimens of *Prunus africana* obtained using primer 25. Populations are separated by thick black lines, and are labelled as follows: B = South African population, R = Ugandan population, J, L and M = Cameroon populations. Specimens in each population were loaded in the order of 'one' to 'five' from left to right within each population. Specimens J4 and R4 are blank as they consistently failed to produce amplification products. The large arrow denotes the direction in which the gel was run, and the small arrow indicates the band that is present in all populations except the South African one.

because there are indications (at least for these template-primer combinations) that band intensity is related to Mg ion concentration (Barker unpublished), all bands were scored.

These data were then analysed using NT-SYS version 1.4 (Rohlf 1988) using the Simple Matching coefficient to provide a matrix of similarity. This coefficient provides a value of similarity between 0 and 1, and is calculated as the m/n, where m is the number of bands in common (presence-presence plus absent-absent occurrences), and n is the sample size. The UPGMA (Unweighted Pair Group Method, Arithmetic average) clustering algorithm was then used to produce a phenogram of relationships between the individuals and populations based on the derived similarity matrix. It must be noted that there are many other possible choices of both similarity coefficient and clustering algorithm, but as all those used gave similar results, only one is presented here.

RESULTS AND DISCUSSION

As this study contains samples from only three geographically disjunct localities, the results presented here must be considered to be preliminary. The

discussion that follows must therefore be viewed in this somewhat limited context. All the primers tested up to this date produced bands which were polymorphic across the geographically widespread populations. In some instances, certain individuals in a population failed to amplify. Where this was occasional, the absence of bands was coded as 'unknown'. However, two samples (one each from the 'R' and 'J' populations) consistently failed to amplify, and therefore these two samples were excluded from the analysis, reducing the number of samples analysed to 23. The causes of the lack of amplification are numerous, but it is likely that an inhibitor is present in the sample, or that the DNA is highly degraded.

The number of bands found, varied from five (primer 28) to 18 (primer 100) per primer across the range of the 23 remaining specimens, with an average of 10.4 bands per primer. A total of 73 different bands were identified, of which 11 were present in all specimens. These 11 bands may therefore be considered to be species-specific. Three bands are exclusively present in all samples of any single population, and may serve as population-level markers. One population is characterized by the absence of a band present in all other populations (Figure 1).

The phenograms based on the presence-absence data clearly indicate that the samples from the three geographically diverse regions are distinct (Figure 2). The level of genetic similarity between the populations of these regions is quite low, indicating minimal gene flow between them. This is most likely to be as a result of their disjunction and restriction to scattered Afromontane habitats. In contrast, the three populations from a single geographical region, those from Cameroon, are not separable into their respective populations on the basis of the RAPD patterns of the seven primers used. This implies that these populations do not each have a unique genetic identity, and that gene flow between them has, at least until recently, been possible.

Unfortunately this preliminary study, which used only seven RAPD primers, was unable to distinguish the geographically closely situated populations. The use of additional primers, as well as the investigation of other sets of geographically close populations, needs to be carried out before any final pattern of genetic diversity can be interpreted with any confidence. However, if the broad range of the genetic diversity of *Prunus africana* is to be conserved, then it appears that geographically distant or isolated populations, such as the three areas studied here, need to be identified as potentially genetically unique, and given some form of conservation status.

If the harvesting of the bark of *Prunus africana* is to continue, urgent attention must be given to the replacement and cultivation of this species, and the use of nondestructive harvesting methods needs to be encouraged. Although steps in this direction have been taken, careful consideration must also be given to the genetic source of material used in replanting programs—seeds should preferably be gathered and grown from local populations, and not be 'imported' from other areas in Africa which possibly have genetically distinct populations of *Prunus africana*.

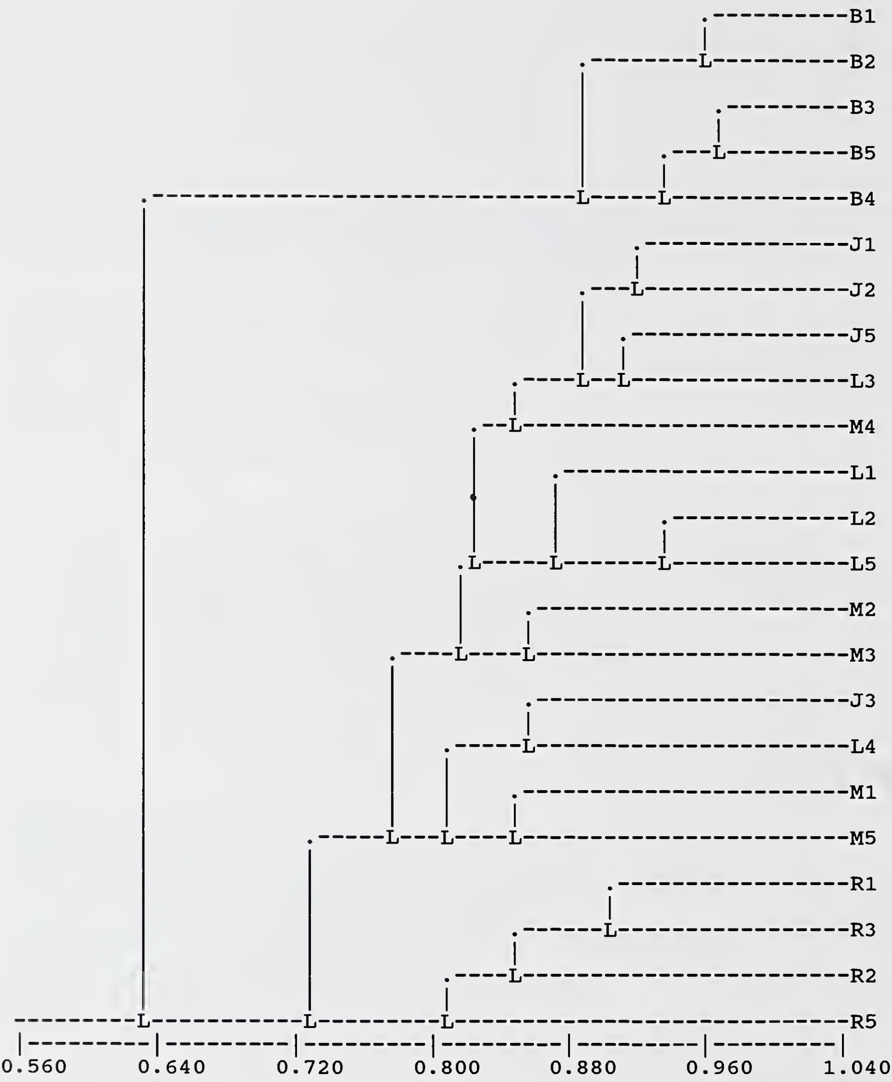

Figure 2.—The phenogram of relationships between specimens of five populations of *Prunus africana* from three geographically diverse regions, obtained by means of the simple matching coefficient and UPGMA clustering algorithm. The line and figures below the phenogram indicate the level of similarity, as calculated according to the Simple Matching coefficient. The genetic diversity within these populations is low, and the three populations from Cameroon are indistinguishable. However, the diversity between the populations from the three countries is quite marked, and they appear as distinct clusters. Key: B = South African population, R = Ugandan population, J, L and M = Cameroon populations. Specimens J4 and R4 are excluded because they consistently failed to produce amplification products.

CONCLUSIONS

Although preliminary, this study has shown the applicability of the RAPD method to the assessment of genetic diversity for conservation and management purposes. The ability of the RAPD primers to 'fingerprint' populations of *Prunus africana*, and the resultant measurement of genetic diversity across these populations and individuals, mean that the impact of population destruction can be assessed, and conservation priorities can be identified. RAPD methods, with all their various advantages, provide a powerful tool for those involved in such diverse disciplines as conservation, resource management, silviculture and germ plasm collection to identify and trace plant material from a wide range of sources.

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Iterative selection procedures: centres of endemism and optimal placement of reserves

A.G. REBELO
Conservation Biology Research Unit, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

ABSTRACT

Southern Africa contains almost 10% of the world's flora. Although high, compared with other regions, the dispersion of these species is not uniform over the subcontinent. One third of this flora occurs on 4% of the area. What are the implications of this with regard to strategies for conserving the floral wealth of the region? Furthermore, what general principles can be deduced from such an analysis and what are the more obvious limitations?

I use two databases to explore the conservation requirements of the subcontinent: PRECIS (PRE [National Herbarium, Pretoria] Computerized Information System) for the subcontinent at quarter-degree grid square scale and the distribution of Proteaceae of the Cape Floral Kingdom at a sixteenth-degree grid square scale.

Undoubtedly, the Cape Floral Kingdom is a prime conservation priority. Nearly half of all the reserves required to optimally protect southern Africa's plant species occur in this region. Results suggest that a strategy for protecting regions of high endemism yields an efficient network in the absence of detailed information. As long as the major centres of endemism are known, obtaining additional data tends to increase one's options by allowing for a more flexible reserve system, without markedly influencing the general location of nature reserves. However, data availability does influence reserve location in areas where certain grid squares are significantly better collected than neighbouring squares. Although probably not serious, severe discrepancies in data collection will bias reserve location to better known sites, thus reducing the flexibility of the reserve system. However, such difficulties can usually be easily resolved by the knowledge of the target species' conservation requirements.

INTRODUCTION

South Africa is experiencing rapid political change, aimed at a just dispensation for all South Africans. History has resulted in a peculiar First and Third World mix as a result of political developments (Huntley *et al.* 1989). As the population of the Third World element increases, the country will undoubtedly become increasingly Third World in character and outlook. This bodes ill for the conservation programme that has developed in a largely First World framework. Even under the most optimistic of scenarios, the rapid economic development required to uplift the quality of life of all South Africans will have to be at the expense of the

environment: dams will have to be built, adequate housing provided and industrial development fostered (Huntley *et al.* loc. cit.).

Perhaps in the light of these political strides, now is the time to take stock of the situation, to consolidate knowledge gained over the last few decades, and to determine priorities. Although this is an essential first step in an efficient conservation strategy (Soule & Kohm 1989), it has not yet been done for southern Africa. Only with such a plan can we enter the turbulent political and bioclimatic future confident that we can manipulate the options available so as to minimize the loss of our biodiversity.

South Africa has signed and will ratify the Convention on Biological Diversity which was presented at the UNCED Rio Summit in June 1992. In terms of the Convention, contracting parties are required to:

'Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes.'

This is important as southern Africa harbours a relatively high proportion (10%) of the world's flora (Siegfried 1989). Furthermore, much of the floristic diversity (over one third of the subcontinent's 22 200 plant species) occurs in a small area (4% of the subcontinent): the Cape Floristic Region (CFR). The CFR is one of the recognized hot-spots in the world (Myers 1990; Rebelo 1991), considered by some as a separate floral kingdom (Takhtajan 1986).

In this paper I first summarize the principles of iterative analysis, then use two databases to explore the conservation requirements of flora of the subcontinent. Using the PRECIS (PRE [National Herbarium, Pretoria] Computerized Information System) database, at a quarter-degree grid square scale, I present an optimal nature reserve configuration to protect the high botanical diversity of the subcontinent. Then, using the distributional data for the Proteaceae of the CFR (at a sixteenth-degree grid square scale), I summarize published findings in the light of the principles of iterative procedures.

PRINCIPLES OF ITERATIVE PROCEDURES

A variety of recent techniques has replaced the old 'scoring approach' which simply ranked predetermined important regions in order of importance (Margules & Usher 1981; Usher 1986; Pressey & Nicholls 1989a). These include hot-spot analysis, gap analysis and various optimizing strategies (Kareiva 1993; Myers 1990; Scott *et al.* 1987). The simplest of these optimizing strategies is iterative procedures (Kirkpatrick & Harwood 1983; Margules *et al.* 1988; Pressey & Nicholls 1989b; Pressey *et al.* 1993; Rebelo & Siegfried 1992; Thomas & Mallorie 1985; Williams *et al.* 1991).

An example of an iterative procedure is shown in Table 1. Imagine a region comprising 16 sites in which we wish to conserve all 15 naturally occurring species.

Hot-spot analysis (Myers 1990; Prendergast *et al.* 1993) would involve summing the species and designating the richest sites (viz. G, H, I and J) as the hot-spots worthy of conservation. As is readily apparent, this setup is redundant (only two of the richest sites are necessary) and falls short of our goals (only 80% of the species are preserved).

In iterative procedures various scoring approaches can be used, such as species richness, endemicity scores, taxic diversity, rarest species and many others. Table 1 shows the procedure utilizing an 'endemicity score', which is the sum of each species's (present in the site) rarity value (total number of sites divided by the number occupied by the species). Of all the scoring approaches, endemicity score regularly gives the most efficient results, and was used in determining the subcontinental and CFR conservation requirements.

At 'iteration 1', the most species-rich site (H) does not contain any endemic species, and therefore scores less than less species-rich sites G and J. Site G is selected for a reserve.

This is where the various scoring approaches and iterative procedures differ. Whereas scoring approaches continue assigning reserves, iterative procedures recognize the fact that some seven species are now adequately preserved (on paper!), leaving the complement—some eight species—still to be preserved [the principle of complementarity (Pressey *et al.* 1993)]. The seven preserved species are therefore dropped from the analysis and the procedure is repeated only on those species that are not adequately preserved in the 15 sites remaining. The result at 'iteration 2' is that site J is selected.

Proceeding to the complement of those preserved in sites G and J (some five species in 14 sites), we select site O. This leaves a complement of only one species and (iteration 4) any of sites L, M or N will equally fulfil the requirement of preserving every species at least once.

The final reserve configuration (G, J, O, L/M/N) illustrates two further principles of optimal reserve configurations evident using iterative procedures: irreplaceability and flexibility.

Two sites are unconditionally irreplaceable. Species 10 and 11 are endemic (confined) to site G and species 12 and 13 are endemic to site J. There is therefore no chance of replacing these two sites. If these sites are not available for conservation, then their endemic species will become extinct in the wild.

On the other hand, sites L, M and N are equally suitable (but sites L and M are additionally preferable over site N by preserving an additional population of species 2). This flexibility is the saving grace of most ideal reserve systems: sites

TABLE 1.—An example of an iterative procedure to conserve all the species in 16 sites in the minimum number of sites. See text for details.

Sites	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Sum	16/sum
Species																		
1	*	*	*	*	*	*	*	*	*	*	*	*	*	*			14	1.14
2			*	*	*	*	*	*	*	*	*	*	*				11	1.45
3						*	*	*	*	*	*						6	2.67
4						*	*	*	*	*							5	3.20
5								*	*	*	*						4	4.00
6								*	*						*		3	5.33
7								*	*						*		3	5.33
8												*	*	*			3	5.33
9							*	*									2	8.00
10							*										1	16.00
11							*										1	16.00
12										*							1	16.00
13										*							1	16.00
14															*	*	2	8.00
15															*	*	2	8.00
Iter. 1																		
	1	1	2	2	2	4	7	8	7	7	4	3	3	2	4	2	No. spp. (*n*=15)	
	1	1	3	3	3	8	48	31	23	44	9	8	8	6	27	16	Σ (16/sum)	
							1	3	5	2					4		Rank (top 5)	
Iter. 2																		
	0	0	0	0	0	0	$	3	3	3	1	1	1	1	4	2	No. spp. (*n*=8)	
							$	14	14	34	4	5	5	5	25	15	Σ (15/sum)	
							$	4	4	1		5	5	5	2	3	Rank (top 5)	
Iter. 3																		
	0	0	0	0	0	0	$	2	2	$	0	1	1	1	4	2	No. spp. (*n*=5)	
							$	9	9	$		5	5	5	23	14	Σ (14/sum)	
							$	3	3	$		4	4	4	1	2	Rank (top 4)	
Iter. 4																		
	0	0	0	0	0	0	$	0	0	$	0	1	1	1	$	0	No. spp. (*n*=1)	
							$			$		4	4	4	$		Σ (13/sum)	
							$			$		1	1	1	$		Rank	
FINAL							$			$		=	=	=	$		4 Res. 25% area	
Key							I			I		F	F	F	IC	IC		
Each × 2							$	$		$		= =	= =	= =	$	$	7 Res. 44% area	
Each × 3							$	$	$	$		$	$	$	$	$	9 Res. 56% area	
Each × 4							$	$	$	$	$	$	$	$	$	$	10 Res. 63% area	
Each × 5						$	$	$	$	$	$	$	$	$	$	$	11 Res. 69% area	
PRE-EXISTING					P		$	P		$				P	=	=	+3 Res. 44% area	

*, species presence; $, selected reserve; =, alternative (flexible) sites; = =, alternative (flexible) sites, any two required; F, flexible sites; I, irreplaceable sites; IC, conditionally irreplaceable site (in the optimal configuration); Iter., iteration; P, existing reserves.

can be selected so as to optimize other factors (such as costs, size of area, proximity to other nature reserves, sociopolitical impacts, etc.).

Sites can be both flexible and irreplaceable. Sites O and P are equally suitable ('flexible'), provided that species 6 and 7 are preserved elsewhere. If only four reserves are possible in the region, then site O is irreplaceable. This irreplaceability is not global, as in the sense of sites G and J, but goal-specific in that it is determined by the goals under which the sites were selected.

Note, therefore, that it is the location of narrow endemics which constrains the optimal reserve configuration. The number of reserves required, their location and the flexibility of the optimal reserve configuration are determined by the number of narrow endemics and their concordance (congruence in distribution ranges). The number of species in the region and the patterns of species richness and turnover between areas are of secondary importance, and may be irrelevant!

Note, furthermore, that iterative procedures are not limited to preserving each species once. Different goals, selection algorithms and secondary considerations (in the event of ties) are possible. Also shown in Table 1 are the optimal configurations for preserving each species in at least two reserves, three reserves, four reserves and five reserves. Similarly, iterative procedures allow for existing reserves to be included in the analysis. Therefore, given that nature reserves exist at sites E, H and N, we require three additional sites to preserve all species at least once, viz. G and J, which are globally irreplaceable, and either of sites O or P (Table 1). This allows for the revaluation of reserves. Therefore, although the reserve at site H preserves over half of all species, it is redundant in terms of our goals if site O is incorporated into the reserve network. Note though that it may be the best option if only a single reserve were allowed in the region! Similarly, the reserve at site E might be more profitably exchanged for another site in terms of the goals outlined above, although it may serve a conservation function independent of our goal.

Also note that the sites need not be grid squares (as used in the examples that follow): regions, farms, districts, fields, or the area of a specific plant population are suitable units. The units do not have to be of equal size, cost, suitability, etc. Similarly, the 'species' do not have to be species: other surrogates (indicator taxa, environmental variables, etc.) and considerations will do equally well, although problems of evaluating cost, size, management criteria, suitability for achieving goals, etc., are best left as ground-truthing of the proposed optimal reserve configuration. Where sites are unsuitable they can subsequently be removed from analysis and the entire procedure easily repeated.

An ideal reserve configuration depends on the initial goals set out to achieve it. The above example illustrates reserve locations, but preserving the species within the site might equally be achieved by restricting land uses to those compatible with the goals (so pastures or dry-land grazing may preserve the target species outside the formal nature reserve system), or the species may be

'rescued' to a seed bank, botanical garden or another site. Similarly, the status of reserves need not be seen as equivalent. In our first example, reserves G and J will probably need to be managed as ecosystems in order to ensure that the processes and symbionts (many of which are unknown) of the species will be maintained indefinitely, whereas reserve L/M/N might be managed as a single-species reserve.

The major benefit of iterative procedures is that each reserve has identified 'target species' within the context of the conservation goals. This allows monitoring and management procedures to be focussed. Any shortcomings, either during the ground-truthing phase of planning the reserve system or when a designated reserve fails to preserve its target species, can be fed back into the database and the analysis readily repeated to identify possible solutions.

Lastly, iterative procedures are one of a set of tools for delimiting an optimal reserve system, i.e. the selection of sites which will preserve as many species in as small an area as possible. Others include linear programming (using matrices), games theory, forward-backward iterative algorithms and several others. The different techniques have different limitations: I will use a simple iterative scoring model, without a backward-searching optimization algorithm in the following analysis. As such the reserves selected approach the optimal configuration, but do not necessarily comprise the smallest possible set. This is because the selection procedure cannot foresee that some species might be selected at later iterations and that a particular site might not be needed within the configuration for this reason. However, this technique (iterative procedures) does not require excessive computer time, allows for larger sample sizes and readily allows for the designation of alternative flexible reserves, at the same time highlighting the relevance and implications of every addition or removal of a site to the reserve system.

TOWARDS A CONSERVATION PLAN FOR SOUTHERN AFRICA

Southern Africa with 22 200 species (and 24 500 taxa) contains just under 10% of the world's flora (Gibbs Russell 1985; Siegfried 1989; modified by C. Hilton-Taylor, pers. comm.). As such it is one of the richest plant areas worldwide. The only available comprehensive database for the distribution of plant species within the region is PRECIS (Arnold & De Wet 1993). At present the database contains data on 19 460 taxa for 3 300 (out of 3 950) quarter-degree grid squares in Botswana, Lesotho, Namibia, South Africa (including TBVC states) and Swaziland, totalling 308 000 records of individual species by grid square. Assuming that these data are a true reflection of southern Africa's flora, they were subjected to several analyses:

Hot-spots: where is the species richness?

Two grid squares contain more than 2 000 species (Table 2). Both are artefacts (they contain both major herbaria and botanical gardens: Cape Town and Pretoria). An additional 26 grid squares contain more than 1 000 species. These are primarily associated with urban areas and known centres of high species richness. A total of 751 grid squares contain more than 100 species. These are largely distributed along the escarpment of southern Africa (Figure 1). The classical hot-spots (gap analysis; Kareiva 1993; Scott *et al.* 1987) would be those grid squares containing more than 200 species (i.e. the top 5%). According to this, there should be a smattering of reserves along the escarpment, along the length of the CFR, with a few additional reserves in the Succulent Karoo (the western escarpment) and the Transvaal highveld. None of the top 5% occur in the Nama-Karoo, the Namib Desert or in Botswana or Namibia.

TABLE 2.—Frequency distribution of number of species (including exotics) per grid square in the PRECIS database

Number of species per grid square	Frequency
1	316
2–5	549
6–10	365
11–50	940
51–100	376
101–500	606
501–1 000	117
1 001–2 000	26
>2 000	2

Irreplaceable hot-spots: where are the narrow endemics?

The distribution area (in quarter-degree grid square units) of species in PRECIS shows that 15% of species are confined to a single degree square (i.e. an area of about 25 × 25 km) (Table 3). Only 2% of the species occur in more than 100 grid squares (3% of the subcontinent's area). Both these figures are likely to be inaccurate: widespread, common species are probably undercollected relative to their area covered, and the rarest species (especially in the CFR) are under-represented in the Pretoria herbarium. Note that 4 540 taxa are not represented in the database—the vast majority of these are probably from the CFR and the Succulent Karoo.

TABLE 3.—Frequency distribution of number of grid squares occupied by a species (including exotics) in the PRECIS database

Number of grid squares per species	Frequency
1	2 960
2–5	5 875
6–10	3 341
11–50	5 875
51–100	1 031
101–500	377
>1 000	1

The distribution of narrow endemics (taxa confined to a single grid square) mirrors the pattern of species richness (Figure 2)—that is, most endemics are found in the southwest of the CFR. In fact, 79% of all grid squares containing more than 10 endemic species ($n = 61$) occur in the CFR. Most of the empty grid squares are in Botswana and eastern Namibia. In detail the geographical pattern of endemism does not reflect species richness: too few endemics occur on the escarp-

ment and many regions of low endemism occur outside the escarpment in the Nama Karoo, Botswana and Namibia. However, there is a strong correlation between species richness and endemicity. This correlation, coupled with the relatively strong clustering of grid squares rich in endemics in the southwest, suggests that a reserve configuration covering a relatively small area of the subcontinent could preserve a high proportion of the botanical diversity.

Iterative analysis: where should the reserves be? (The ideal configuration)

The optimal reserve configuration, as determined by iterative procedures (Figure 3), requires some 877 grid squares or 22% of the area of the subcontinent to preserve all the species at least once. However, much of this area is required to preserve a small fraction of the species (Figure 4): thus half the taxa can be preserved in 16 grid squares (0.4% of the area), and 90% in 202 grid squares (5%

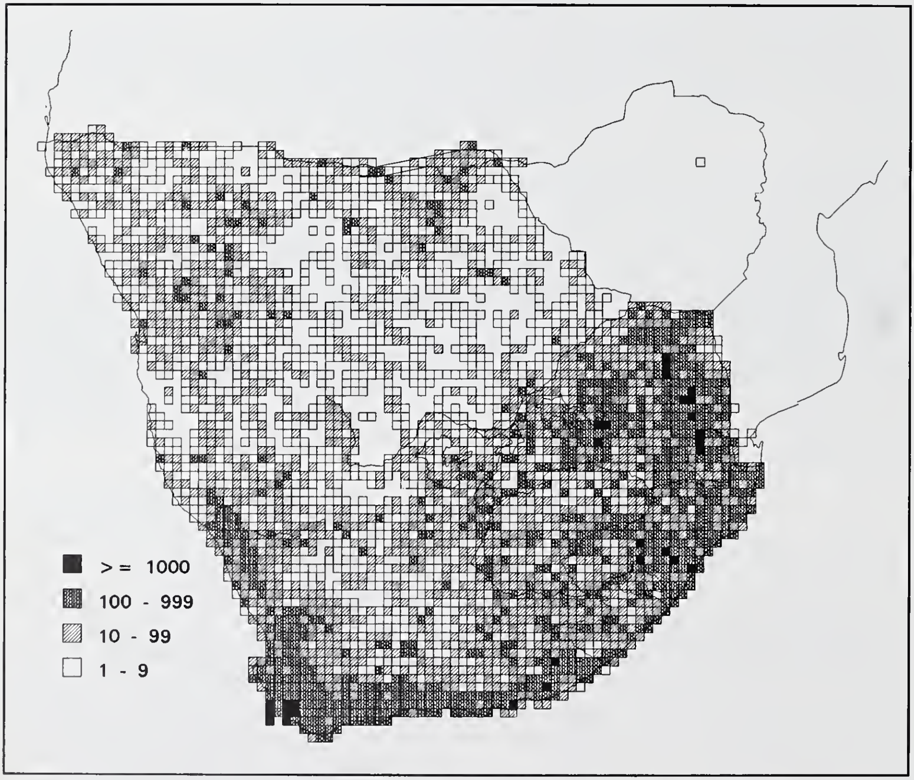

Figure 1.—Hot-spots in the southern African flora, showing the number of plant species per degree square. Classical 'hot-spots' would include the top 5% of cells, or those grid squares with more than 200 species.

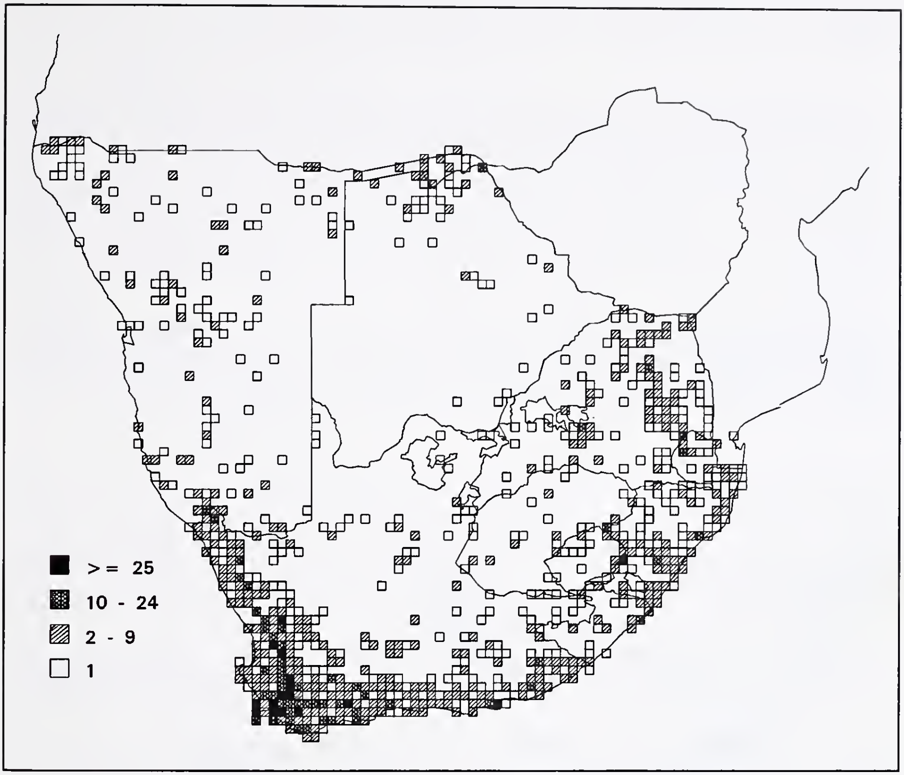

Figure 2.—The distribution of narrow endemics (those confined to a single degree square) per degree square in the southern African flora. These form the irreplaceable component of the optimal reserve configuration.

of the area). In an optimal configuration, 10% of southern Africa's area can preserve 18 005 taxa, or 93% of the taxa.

Furthermore, of the 877 required reserves in the optimal configuration, some 787 (90%) are irreplaceable, the remaining 90 grid squares being flexible to a varying extent.

Where should these optimal nature reserves be situated? Obviously, all grid squares with endemic species are included (see 'Irreplaceable hot-spots'). The flexible reserves are randomly scattered throughout the region, except in the Succulent Karoo and CFR where the entire reserve configuration is irreplaceable!

Gap analysis: where should reserves be located given the existing reserve network?

The configuration of the existing reserve network is shown in Figure 5. The only database available at present (courtesy of the Percy FitzPatrick Institute of African Ornithology) gives those grid squares that contain a proclaimed national or provincial nature reserve, irrespective of the area of the grid square covered by the reserve. According to these data, some 866 grid squares (22% of the subcontinent's area) currently contain reserves, and these grid squares contain (and may protect) some 89.9% of the flora of southern Africa (Figure 6).

Where are the areas which should be conserved? Gap analysis (Kareiva 1993) can be used (although typically it uses the hot-spot approach outlined above) to investigate the spatial pattern of existing reserves relative to the ideal:

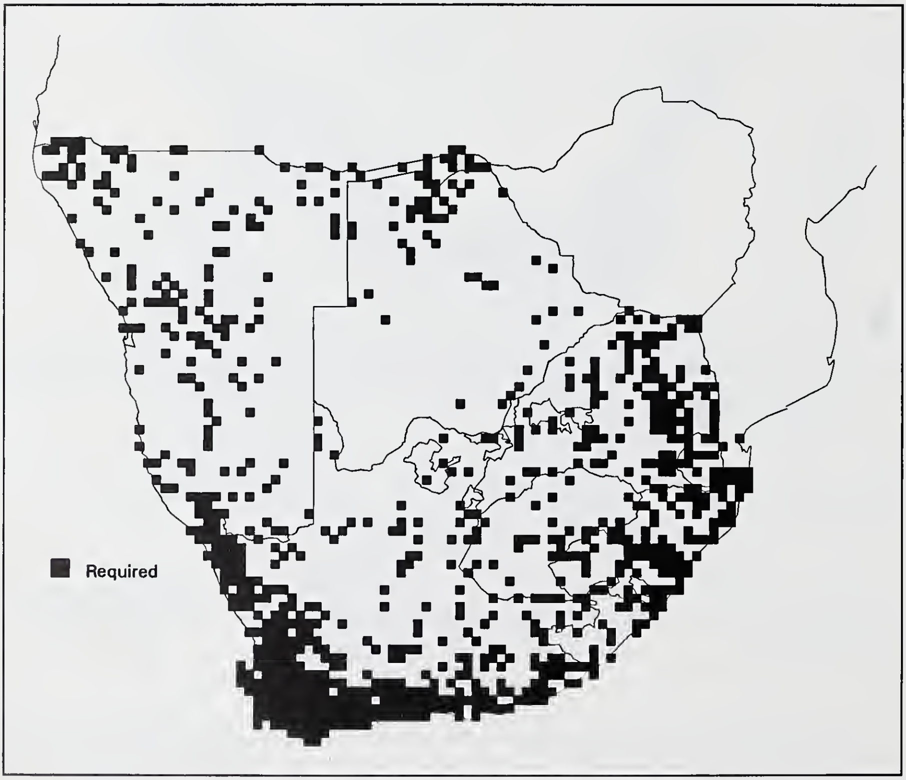

Figure 3.—The optimal reserve configuration for the southern African flora, as determined by iterative analysis. As is evident from a comparison with Figure 2, some 90% of the grid squares are irreplaceable.

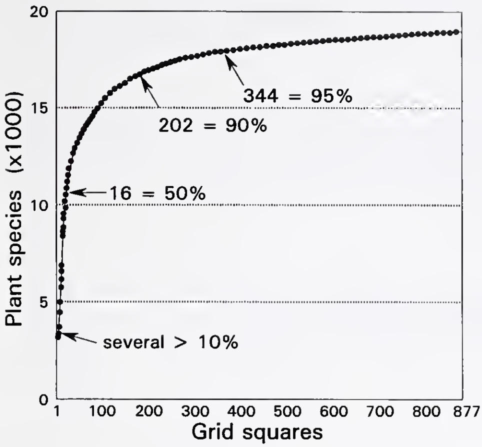

Figure 4.—The relationship between area required (out of 3 950 grid squares) and number of plant species represented in the optimal reserve configuration for the flora of southern Africa.

some 516 grid squares within the optimal configuration do not occur in the existing reserve system (Figure 5). On the basis of this a further 13% of the area of southern Africa is required to preserve all the species. By far the majority of these areas are in the Succulent Karoo on the west coast, and the escarpment of Namibia (Figure 5).

Iterative analysis: where should additional reserves be? (Current requirements and priorities)

The problem with gap analysis as outlined above is that it ignores the principle of complementarity. The 866 grid squares with reserves contribute more to the reserve configuration than preserving 89.9% of the flora—they actually change the configuration of the required flexible reserves.

Therefore, given a reserve system of 866 grid squares shown in Figure 5, a further 499 grid squares are required to protect the entire flora. The error in the gap analysis estimate is therefore 17 grid squares (0.4% of the area of southern Africa or 10 625 km^2). The efficiency of the existing reserve system therefore is [(existing + required)/optimal]:

$$(866 + 499)/877 = 1.56$$

or requiring an area one and a half times larger than optimal (Figure 6).

Furthermore, of the 866 grid squares of the existing reserve network, only 361 are optimal. Therefore, since the additional reserves required (499) add up to 860 grid squares, and the optimal reserve system is 877, the 505 'nonoptimal' reserve grid squares are the equivalent of 17 reserves in the optimal configuration. Furthermore, the last 10% of species require fully one third of the total reserve system under the existing reserve system. In reality, many of these areas function

to preserve only one or two species, and can be considered for reserves much smaller than the grid square in extent.

Given that the existing reserve system in fact covers about 6–8% of the area of the subcontinent (Siegfried 1989) (versus 22% by grid square), this suggests that perhaps the optimal reserve system may be as small as 11%. But this assumes that all the target species in the 'reserved' grid squares are preserved, which is almost certainly not the case.

The location of the required reserves is shown in Figure 7. The largest contiguous area requiring preservation that currently has the fewest reserves is the Succulent Karoo (Cowling & Hilton Taylor 1994; Hilton-Taylor & Le Roux

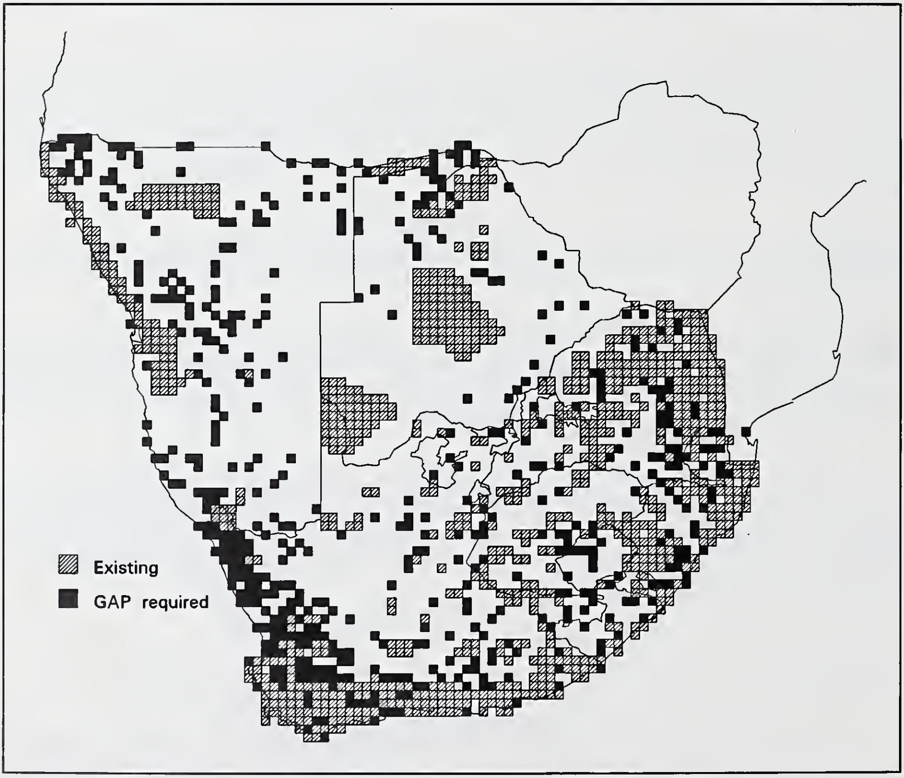

Figure 5.—The configuration of the existing reserve network (grid squares containing a nature reserve in South Africa, or with more than half the area preserved in Namibia and Botswana—solid shading) in southern Africa, superimposed on the optimal reserve configuration—hatched shading.

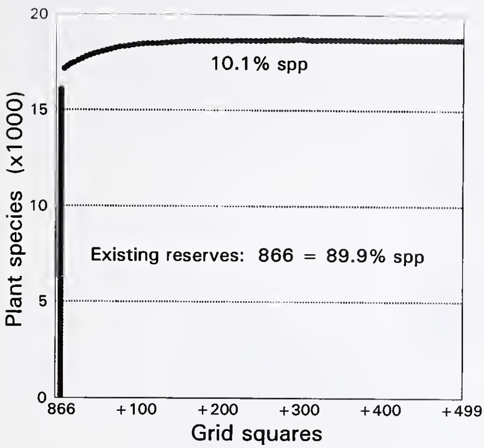

Figure 6.—The relationship between area required and number of plant species preserved given the current reserve network for the flora of southern Africa.

1989). Other major gaps include the northern CFR, much of central Namibia and odd sites within the existing reserve system in the rest of southern Africa.

Problems with the analysis

- incomplete data (errors of omission)

PRECIS is incomplete. Some grid squares are estimated to have records for only 17% of their flora (Gibbs Russell *et al.* 1984). The major effect of this lack of data is that the actual flexibility of the optimal reserve system is compromised. More data are likely to increase flexibility, rather than bring to light additional irreplaceable grid squares. This assumes that major centres of endemism are all known and that additional new species are more likely to be found in grid squares containing many endemics than in species-poor, endemic-poor ones. Other than the observation that the 2 960 narrow endemics in PRECIS occur in 787 grid squares, with 22 grid squares containing more than 20 narrow endemics and more than 500 species each, there are few data to indicate whether undescribed species are likely to occur in species-rich or endemic-rich grid squares.

- incorrect data (errors of commission)

PRECIS has a high proportion of incorrect data. Certainly, species determinations within the CFR have a very high error rate (15–31% by species—Rebelo & Cowling 1991), although for grasses this error is estimated at only 5–15% (G.E. Gibbs Russell pers. comm.). These errors suggest that a simple geographic check would resolve a significant proportion of problems (Rebelo & Cowling 1991).

The second problem is incorrect localities. Some are simple coding errors, but an unacceptably high level of correlated errors exist, probably brought about by

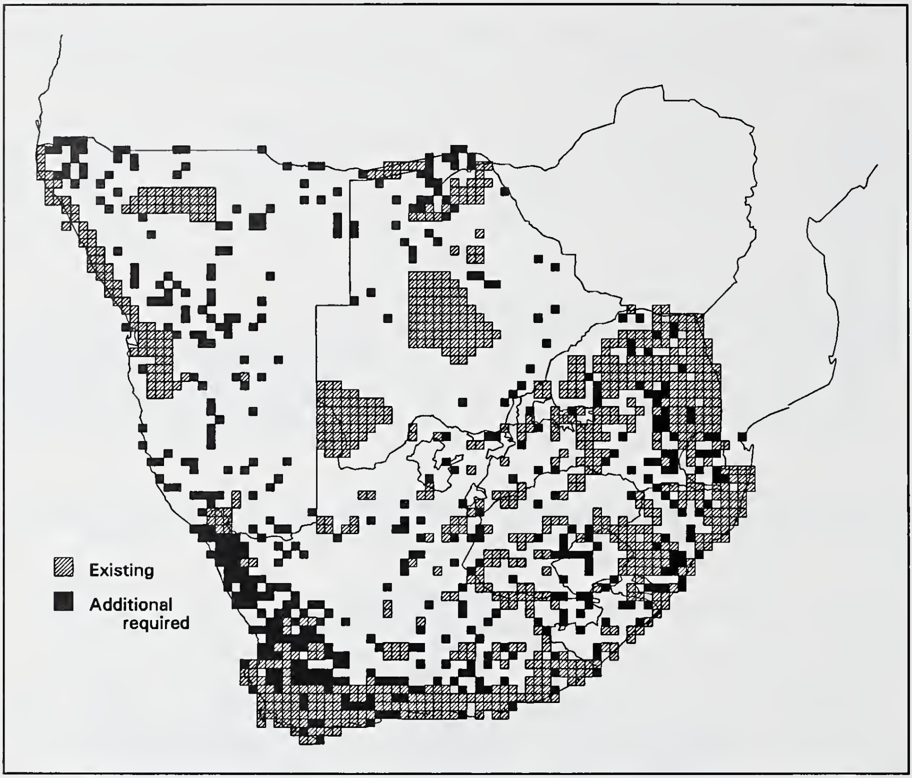

Figure 7.—The configuration of nature reserves required to represent all plant taxa in southern Africa once, given the existing reserve network (see Figure 5) as determined by iterative analysis.

extrapolating localities from an inadequate gazetteer. In addition, consistent coding errors result in certain grid squares regularly being transposed (K. Braun pers. comm.). This problem is exacerbated by poorly delineated localities being ascribed to the grid square containing the nominal town of the district.

Similarly, incompletely labelled data have resulted in a high proportion of planted species included in the database, without any indication that this may be the case. This especially affects the major cities with local botanical gardens and herbaria. Exotic plants are relatively easy to extract, and were not included in the above analysis.

It is difficult to gauge the cumulative effects of such errors on optimal reserve configurations. In some cases errors will artificially inflate flexibility, in others incorrect areas will be designated as irreplaceable. However, sufficient endemic species probably exist in most centres of endemism to ensure that the 'real-world'

minimum set is included within the 'noisy' data, although isolated endemic species might fall through the net. Far more problematic, and readily apparent in the above analysis, is the overevaluation of cities as areas of conservation worthiness, when in fact a significant proportion of the species targeted are exotic to the designated grid square. The selection of cities might also reflect another problem, namely uneven coverage.

- uneven coverage

Despite the obvious question of how good the PRECIS coverage is over the entire subcontinent, we cannot find a good measure of this. Accounts of species richness are published, as are the number of specimens per grid square, but no account is taken of the fact that the number of specimens might be a function of the number of species present. The number of specimens per taxon are presented in Figure 8. With the exception of the Nama Karoo and most of Namibia and

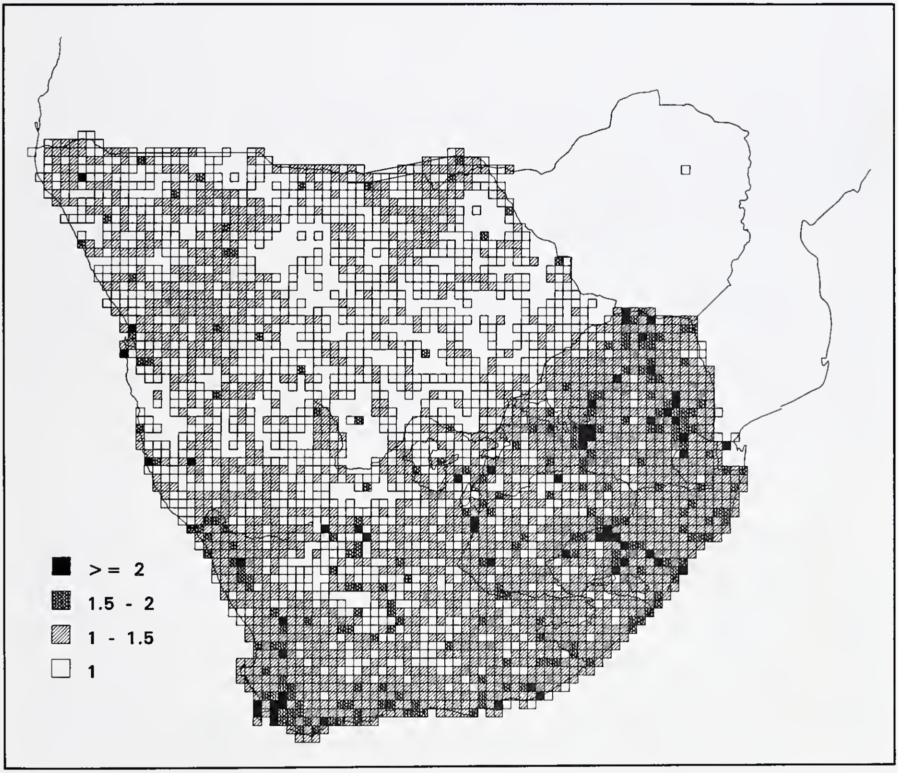

Figure 8.—The number of herbarium records per plant species recorded per degree square for southern Africa in the PRECIS database.

Botswana which have only one specimen per taxon, most grid squares have between one and two specimens per taxon. Grid squares with more than two specimens per taxon occur around major cities and certain nature reserves. Further analysis of these biases is urgently required.

The bias of good coverage to nature reserves is a major limitation in designating conservation systems as they bias available data towards supporting the existing nature reserve configuration, rather than being a truly independent data set. Likewise, it is crucial when updating existing databases to ensure that areas selected as important for conservation are not made the focus of further data collection (or if so, that the data are kept separate) or else the database will start 'proving' and 'justifying' its predictions.

- scale

The reserve data, species distributional data and reserve prescriptions are all bound by the largest scale of error available—the quarter-degree square. Certainly, this scale is too coarse for analysing patterns of species richness in the CFR (Rebelo & Siegfried 1989). Similarly, it is far too coarse for prescribing reserve locations within southern Africa. The only solution is to use the prescription as a guide to which species are required to be preserved in each grid square designated. This prescription stipulates the conservation requirements of the region in a subcontinental context. It may therefore be possible to meet these requirements in a few hectares in one grid square, but require two or more grid squares to meet similar requirements elsewhere, depending on the autecology of the species in question and its symbionts (Bond 1989; Cowling & Bond 1991). Furthermore, this approach allows the optimal reserve configuration to be ground-truthed, verified, updated, reoptimized and continually reassessed as reserves are designated; sites become transformed or otherwise unavailable for conservation; land-use patterns affect the conservation requirements of a particular species; species become protected by other means; or the subcontinental conservation goals and strategies are modified. Fortunately iterative procedures can readily be run on standard databases as new data become available.

- other limitations of the database

PRECIS is primarily a curatorial tool (Gibbs Russell & Gonsalves 1984). It does not attempt geographical or systematic representativeness (Gibbs Russell *et al.* 1984). Biases within the database reflect past research foci, collectors' preferences and excursions to exotic, favourite, species-rich and under-collected regions. Use of this database outside of systematics and curation must bear this in mind, although attempts are being made to make the database geographically comprehensive (Gibbs Russell & Gonsalves 1984). Furthermore, PRECIS is a historical collection—it does not convey much information on the current distributions of species: long-extinct populations should feature in PRECIS indefinitely. These data must therefore be ground-truthed before finalizing reserve prescriptions.

THE CAPE FLORISTIC REGION

The Cape Floristic Region (CFR) is one of the world's six Floral Kingdoms (Takhtajan 1986). It has the richest flora of the five Mediterranean climatic regions, which generally have the richest temperate floras, and exceeds that of most tropical and island floras in terms of the proportion of endemic plant taxa (Bond & Goldblatt 1984; Table 4). Although it occupies an area of only 90 000 km^2, the CFR contains more than twice as many species (8 600) as any island of similar size (Bond & Goldblatt 1984). Over 60% of the *Red data book* plant species of southern Africa occur in the CFR, which comprises only 4% of the subcontinent's area (Hall & Veldhuis 1985). Together with the remaining tropical rain forests, the CFR must be considered one of the world's top conservation priorities (Macdonald 1989; Myers 1990).

However, the major problem is that in southern Africa, species' distributional data are routinely mapped at the quarter-degree grid scale (Edwards & Leistner 1971), with units measuring *ca.* 24 × 27 km in the CFR. However, the CFR consists of a network of mountain vs. plain topographies, and nutrient-poor vs. nutrient-rich soils. The quarter-degree grid system is too coarse for describing the spatial scale of phytogeographical heterogeneity (Rebelo & Siegfried 1989). To this end distributional data for the Proteaceae were mapped on an eighth-degree square system (12 × 13 km). Since the patterns of species richness at a quarter-degree grid scale are significantly correlated with all other endemic or species-rich families in the CFR, we assume that this family adequately represents the patterns and processes at work in the CFR (Rebelo & Siegfried 1989).

TABLE 4.—The relative position of the CFR compared to the ten top 'hot-spot' areas in tropical forests (Myers 1988 in McNeely *et al.* 1990), ranked by number of endemic plant species

Area	Original extent (km^2)	Currently un-transformed (% original)	Plant species		A/B (%)
			Total (A)	Endemics (B)	
Cape Floristic Region	90 000	67	8 600	5 800	67
Atlantic Forest, Brazil	1 000 000	2	10 000	5 000	50
W. Amazonian Uplands	100 000	35	20 000	5 000	25
Madagascar	62 000	16	6 000	4 900	82
Philippines	250 000	3	8 500	3 700	44
Northern Borneo	190 000	34	9 000	3 500	39
Eastern Himalayas	340 000	16	9 000	3 500	39
Western Ecuador	27 000	9	10 000	2 500	25
Colombian Choco	100 000	72	10 000	2 500	25
Peninsular Malaysia	120 000	22	8 500	2 400	28
New Caledonia	15 000	10	1 580	1 400	89
Alternative rankings by:	put the CFR in position no.:				
Proportion of endemic species	3				
Total plant species	7				
Proportion of area remaining	10				

Existing reserves

The location of existing reserves is shown in Figure 9. Some 19% of the CFR (1.78 Mha) is preserved in statutory, private and contractual nature reserves (Rebelo 1992b). By far the largest proportion (79%) of statutory preserved land (1.1 Mha) in the CFR was proclaimed as mountain water catchment areas for an arid South Africa (Huntley 1978). A recent development (post-1970) has been the proclamation of contractual preservation areas as mountain catchment areas and contractual national parks, which currently comprise 39% of the preserved area. These areas allow grazing, game farming, and flower and plant harvesting on a scale compatible with ecosystem preservation, and are managed as larger units in combination with state water catchment areas (Rebelo 1992a).

It is probably true to state that almost all extant bird and nonflying mammal (>95%), reptile and amphibian species (>90%) and about 93% of mountain fynbos plant species in the CFR occur in statutory nature reserves (Rebelo & Siegfried 1989; Siegfried 1989). However, this statement has excluded the lowlands of the CFR. There is only one fynbos reserve larger than 1 000 ha in the lowlands, and

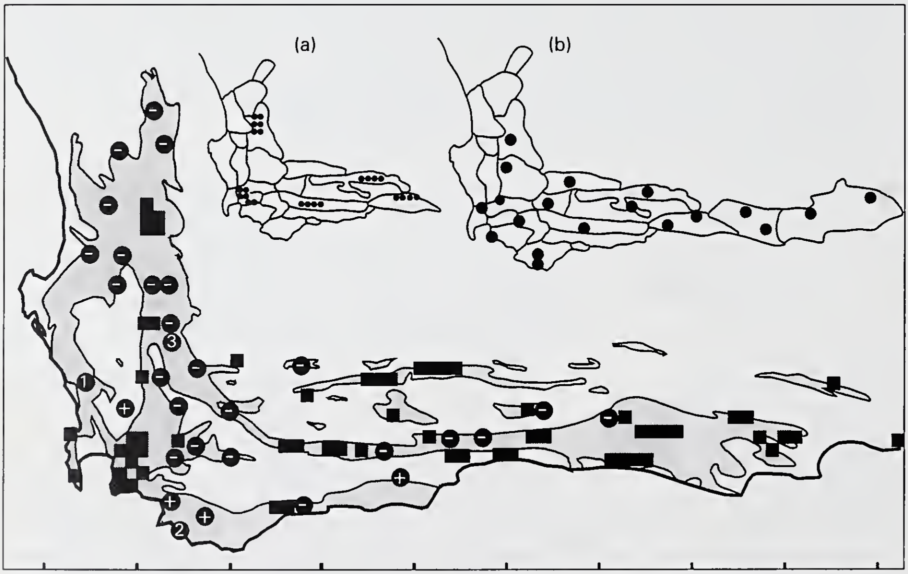

Figure 9.—The location of grid squares in the Cape Floristic Region containing more than half their area in nature reserves (solid squares). Additional reserves required to represent all Proteaceae species in the region (dots) are categorized as: numerals (in order of importance) = reserves required to represent more than four species; + = those representing three species; – = those representing one or two species. Inset: prescriptions for reserve configurations by (a) Wicht (1945) and (b) Kruger (1977).

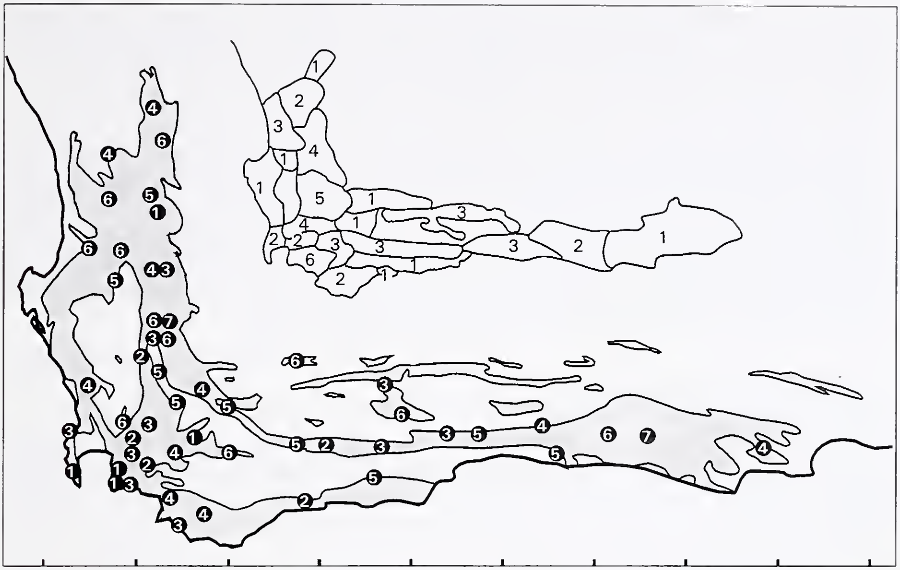

Figure 10.—One of 10^{13} optimal reserve configurations for representing all Proteaceae in the Cape Floristic Region in 52 reserves. This configuration additionally represents each species in as many reserves as possible. Inset: centres of endemism for Proteaceae in the Cape Floristic Region. Numerals are the number of reserves required in each centre for the optimal reserve configuration.

a total of 15 000 ha of renosterveld vegetation has been preserved (Rebelo 1992a). No estimates of the conservation effectiveness of the lowland reserve system have been made to date.

Historical prescriptions

The current reserve network is based on Wicht's (1945) prescription, which arose out of concern about the destruction of fynbos because of its perceived low economic value, and the desire to transform it to a productive state. He designated five reserves as a core system to preserve fynbos for its aesthetic and general scientific value by conserving the natural vegetation in 'well selected, representative, relatively large regions, which should be maintained with painstaking care'. This was achieved by selecting large areas of high species richness in each of the five major mountain ranges. This system theoretically preserves 52% of Proteaceae species in 24 grid squares and (using iterative procedures) requires a total of 72 grid squares to preserve all the species.

Kruger (1977) proposed that each major CFR vegetation type in each of Weimarck's (1941) centres of endemism should be preserved. He did not specify

where within the 19 zones identified the reserves should be located. Assuming that the most species-rich grid square in each zone is selected, this system preserves 64% of the Proteaceae species in 19 grid squares and requires a total of 64 grid squares to preserve all the species.

A random selection of grid squares containing more than two species, yielded results indistinguishable from both Wicht's (1945) prescription and the existing reserve network. The existing reserve network, selected as those grid squares with more than 55% of the area preserved in statutory nature reserves, preserved 265 species in 66 grid squares, but required 98 grid squares to preserve all the species. Only Kruger's (1977) procedure performed significantly better than predicted using the random selection (Rebelo & Siegfried 1993).

The ideal reserve configurations

The above prescriptions beg the question of what the optimal reserve configuration to preserve the entire flora in the minimum number of grid squares might be. By means of the iterative approach, reserves were selected using an endemicity algorithm (Rebelo & Siegfried 1992) for the 857 grid squares comprising the CFR.

Iterative procedures suggest that the optimal reserve configuration comprises 53 grid squares (Figure 10). However, it is possible to preserve all the species in 52 reserves. This inefficiency is due to the inappropriate selection of grid squares when ties occurred (Rebelo & Siegfried 1992).

From these results it is apparent that the spatial configuration of nature reserves is determined primarily by the location of the most geographically restricted species. More widespread species are invariably included within these reserves. The relative number of species shared between grid squares (including surrogate measures, such as Sorenson's coefficient of community) is irrelevant because narrowly endemic species are the focus of efficient reserve location (Rebelo & Siegfried 1992). For this reason it is not possible to accurately determine the efficiency of any reserve configuration based on the number of species preserved or the area (number of grid squares) set aside. The only reliable index of the efficiency of a reserve system is the additional area required to preserve all the species (Rebelo & Siegfried 1992).

In the absence of detailed data, the selection of areas rich in narrowly endemic species will optimally preserve species richness. Where endemic species have congruent distributions, preservation in a fraction of the region under consideration will be possible. Conservation will be problematic in regions where endemic species have contiguous distribution ranges. Unfortunately, the worldwide patterns of species richness relative to endemicity are poorly known.

There is also not only one ideal reserve configuration for any system. Where endemic species have relatively wide distribution ranges, the number of potential alternative configurations will be greater. In the CFR there are about 5×10^{13}

alternative configurations which preserve all 331 Proteaceae species in 53 grid squares (Figure 11).

In the CFR, increasing the number of grid squares in which all species must be preserved, results in a near linear increase in number of grid squares required in the reserve system. Therefore, to preserve each species twice and four times requires 105 and 178 grid squares, respectively. Again the relationship is determined primarily by the distribution of narrowly endemic species: where congruence of endemic species is high or where endemics are relatively widespread, the relationship between number of reserves required per species and total area will be flatter than for contiguous endemics with narrow distribution ranges.

Conservation requirements

The existing reserve network is little better than a random selection of grid squares. Although it preserves 80% of Proteaceae species, a further 32 grid squares are required to preserve all the species (Figure 9). The existing reserve

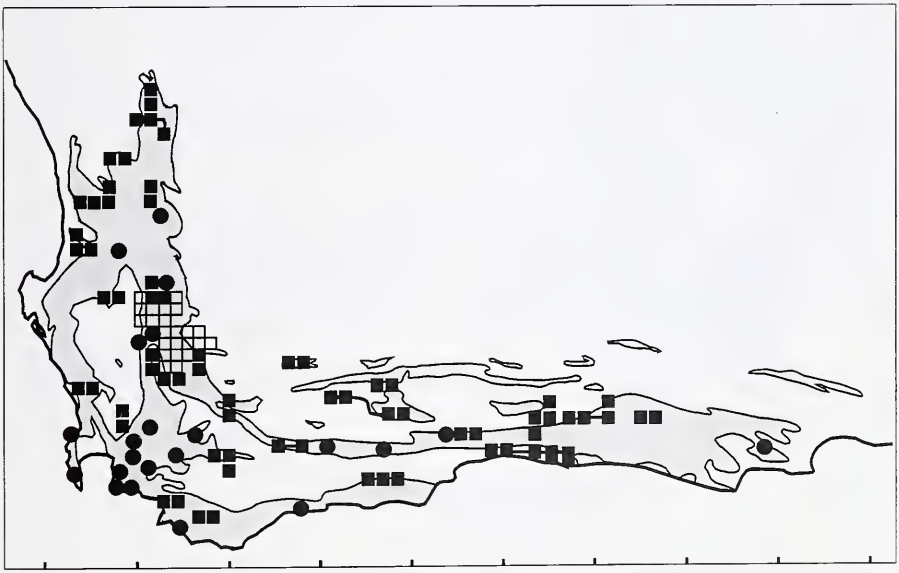

Figure 11.—The 10^{13} alternative sitings to represent all species of Proteaceae in the Cape Floristic Region in 52 reserves. Dots are irreplaceable reserves. Contiguous black grid squares and those linked by lines are flexible sets for which any one grid square would equally well achieve the stated goal. The open squares circumscribe an area in which any reserve would probably suffice given inadequacies in existing data.

system therefore requires nearly twice (1.87 times) as many grid squares as the optimal configuration to preserve all the species once.

From the spatial configuration of additional nature reserves required to augment the current reserve system, it is apparent that the lowlands of the CFR are

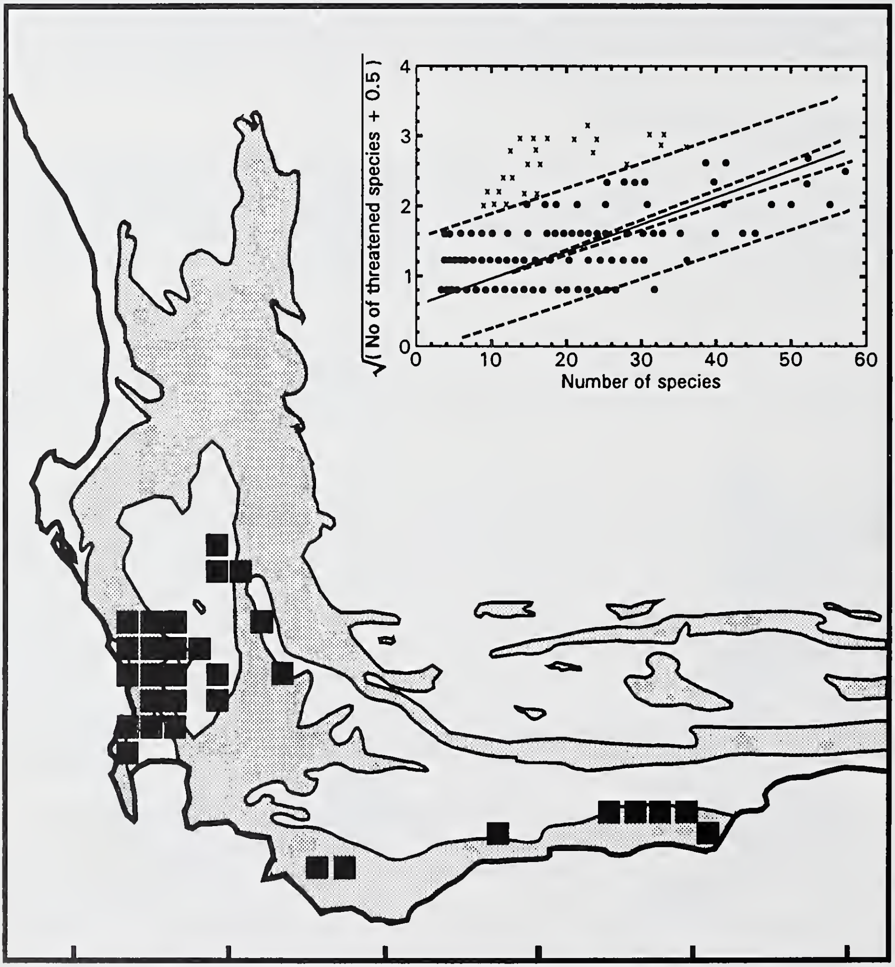

Figure 12.—*Red data book* threatened plant species richness relative to total plant species richness: priority hot-spots. Since the number of *Red data book* species is strongly correlated to species richness (inset: $r = 0.798$, $P < 0.001$), it is essential to correct for this in order to delimit regions with more *Red data book* species than expected.

the top priority conservation areas, with the central region requiring additional conservation status (Figure 9). Three of the required 32 nature reserves preserve more than three target species, and four preserve three target species. These should perhaps be considered for large ecologically viable reserves. The remaining grid squares preserve only one or two target species and can perhaps be preserved in very much smaller areas.

Another major concern is that data are not evenly available throughout the CFR—many remote areas are botanically poorly known. However, provided new species are not found, additional records of species will increase the number of potential reserve configurations without affecting the total number of reserves required. Specifically as data on poorly known endemic species increase, so does the number of potential alternative configurations for that target taxon. Furthermore, the likelihood of a major centre of endemism having been missed is low, and new species are probably most likely to be found within the existing centres of endemism which also have a high species richness.

Priorities

Red data books provide data which allow the designation of areas containing an abundance of threatened taxa (Ferrar 1989). A *Red data book* for plants is available for the CFR (Hall & Veldhuis 1985). As *Red data books* provide data which allow the designation of 'hot-spots', or noda of threatened species, considerable conservation effort should be directed towards these noda (Prendergast *et al.* 1993). However, given a geographically constant threat which is experienced over a relatively wide geographical area, areas containing more species are likely to have more *Red data book* species.

Red data book Proteaceae species richness in the CFR (Tansley 1988) is significantly correlated ($P < 0.001$) with total Proteaceae species richness at an eighth-degree grid scale, and with total *Red data book* species richness at a quarter-degree scale (Rebelo & Tansley 1993). Total *Red data book* species richness is also significantly correlated ($P < 0.001$) with total species richness at a quarter-degree scale in the CFR.

Furthermore, the distribution of threatened species (i.e. vulnerable, endangered and extinct) is geographically distinct from that of naturally rare species. The distribution of threatened species (Figure 12) is in agreement with the findings of the only assessment of conservation priorities (in the lowlands) of the CFR (Jarman 1986) done to date. The greatest threat to plant species in the CFR is the urban expansion of Cape Town (Rebelo & Tansley 1993). To some extent this applies to other taxa such as butterflies and frogs as well (Rebelo 1992b).

However, within grid squares in the greater Cape Town metropolitan area, *Red data book* Proteaceae richness significantly underestimated total *Red data book* species richness (Rebelo & Siegfried 1992). These grid squares also contain local populations of more widespread species, which are not included in the

Red data book because the threat to them is localized. Therefore the threats in the region are underestimated in our analysis using the Proteaceae (Rebelo & Tansley 1993).

These results are in concordance with a survey of natural lowland remnants in the greater Cape Town metropolitan area, which revealed 74 threatened species surviving in the remaining 484 ha of natural and seminatural vegetation, i.e. the arithmetic equivalent of 15 threatened species per km^2 (McDowell *et al.* 1991). This area must rank as one of the top priority conservation areas worldwide, and is primarily impacted by the expansion of the peri-urban areas over much of one of the richer centres of endemism within the CFR (Wood *et al.* 1994).

CONCLUSIONS

A few principles can be derived from iterative procedures:

1. Local endemics are the most important focus of conservation actions. Common species will be caught in any reserve network, although the network should be checked to ensure that some reserves are able to meet the conservation requirements of each common species.

2. Reserve locations can be flexible or irreplaceable—this depends primarily on the pattern of localized endemic species.

3. The spatial location of reserves is determined by existing reserves, current land availability and conservation goals, and, with the exception of irreplaceable sites, may change with every reserve added or area for which conservation options are foreclosed.

4. The size, exact location, management goals and running costs of a reserve should be determined by those species that the reserve is designed to protect within the regional milieu: chiefly its localized endemics and other representative species. Any deviation from this strategy will affect the efficiency and spatial configuration of the conservation network.

5. If optimal reserve configurations are not attainable, the alternatives may be much more extensive and expensive.

6. In the absence of detailed data, the optimal approach is to preserve the localized endemics (especially within areas noted for high endemicity) and, within these, to emphasize those areas with high species richness.

Quo vadis?

Before a national or subcontinental optimum strategy can be finalized, we need to assess whether the available data are adequate to achieve this. This can be done by computerizing the data on specimens in the Cape (especially those

of the National Botanical Institute), Harare, Maputo, Natal and Windhoek herbaria. Not only will these fill in the currently acknowledged gaps, but a comparative analysis would allow a detailed assessment of the problems inherent with incomplete data. My gut feeling is that the irreplaceable components of the reserve configuration will be indistinguishable, although flexibility will increase considerably.

Although data are lacking, I feel too that it is essential to develop conservation plans for ecologically meaningful regions. Political regions are likely to have a high number of peripheral species (species which are common outside the region, but are rare within the region—these usually occur near the borders). These 'politically' rare species will distort reserve configurations by overvaluing species that can be better preserved elsewhere. A similar problem exists for *Red data books* (Ferrar 1987). To my mind, the entire subcontinent should be treated as a unit and cross-border reserves encouraged.

It must also be acknowledged that regional and subcontinental requirements will differ! Therefore, although large areas of arid savanna occur in Namibia, they might perhaps be better preserved in Botswana within the subcontinental framework. However, within the local Namibian framework, arid savannas might rate higher than subcontinentally rare associations which are locally abundant. Such conflicts need to be identified and a politically acceptable strategy implemented.

Southern Africa is currently in a unique position of being the first region of significant botanical biodiversity to be able to plan a comprehensive regional conservation strategy to preserve its biodiversity. The winds of change have blown across the continent many times. It is time to prepare an action plan for conservation so that we can hedge our bets between possible political outcomes, or as a last resort, at least document the loss of diversity. Ideally, by the year 2000 we should have both a plan of action and a clear idea of which way the wind is blowing.

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Threats to plant species diversity through urbanization and habitat fragmentation in the Cape Metropolitan Area, South Africa

J. WOOD*, A.B. LOW**, J.S. DONALDSON* and A.G. REBELO*

* Conservation Biology Research Unit, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.
** National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

ABSTRACT

The Cape Metropolitan Area (CMA), which lies in the Cape Floristic Region, contains three centres of endemism for fynbos plant species: the Cape Peninsula, Cape Flats and Darling/Dassenberg area. Rapid urban expansion has resulted in the extinction or near extinction of many plant species. This situation is particularly true of the Cape Flats where only isolated remnants of fynbos vegetation remain. These contain exceptionally high concentrations of *Red data book* plant species (15.3 taxa/km^2) and endemics (4.96 taxa/km^2). One of the next major urban growth axes in the Cape Metropolitan Area is northwards into the relatively undeveloped Darling/Dassenberg centre. Therefore the need for incorporating conservation requirements into town planning is essential for the preservation of biotic diversity within the CMA.

INTRODUCTION

The Cape Floristic Region (CFR) is an area with extraordinary plant species richness and a high proportion of endemic species (Cowling *et al.* 1992; Gentry 1986; Goldblatt 1978; Linder 1985; Major 1988). The flora is in fact so remarkable that the CFR has been identified as a conservation ‘hot-spot’ of international significance (Myers 1990; Rebelo 1994). In the southwest corner of this floristically important region lies the Cape Metropolitan Area (CMA, Figure 1), a zone incorporating extensive urban development in the greater Cape Town area as well as potential sites for future urban expansion.

Until recently, little attention was paid to conserving the natural environment when planning for urban development. Open space planning to date has favoured well manicured landscapes and exotic plantings (Roberts & Poynton 1985). Furthermore, compacted or informal communities were developed with little or no open space (City Engineer’s Department 1982). The possible effects of this type of development and subsequent habitat loss are illustrated by the high number of plant species (294) in the CMA which have been classified as being in immediate danger of extinction (Hall & Veldhuis 1985; McDowell & Low 1990; Rebelo 1992a;

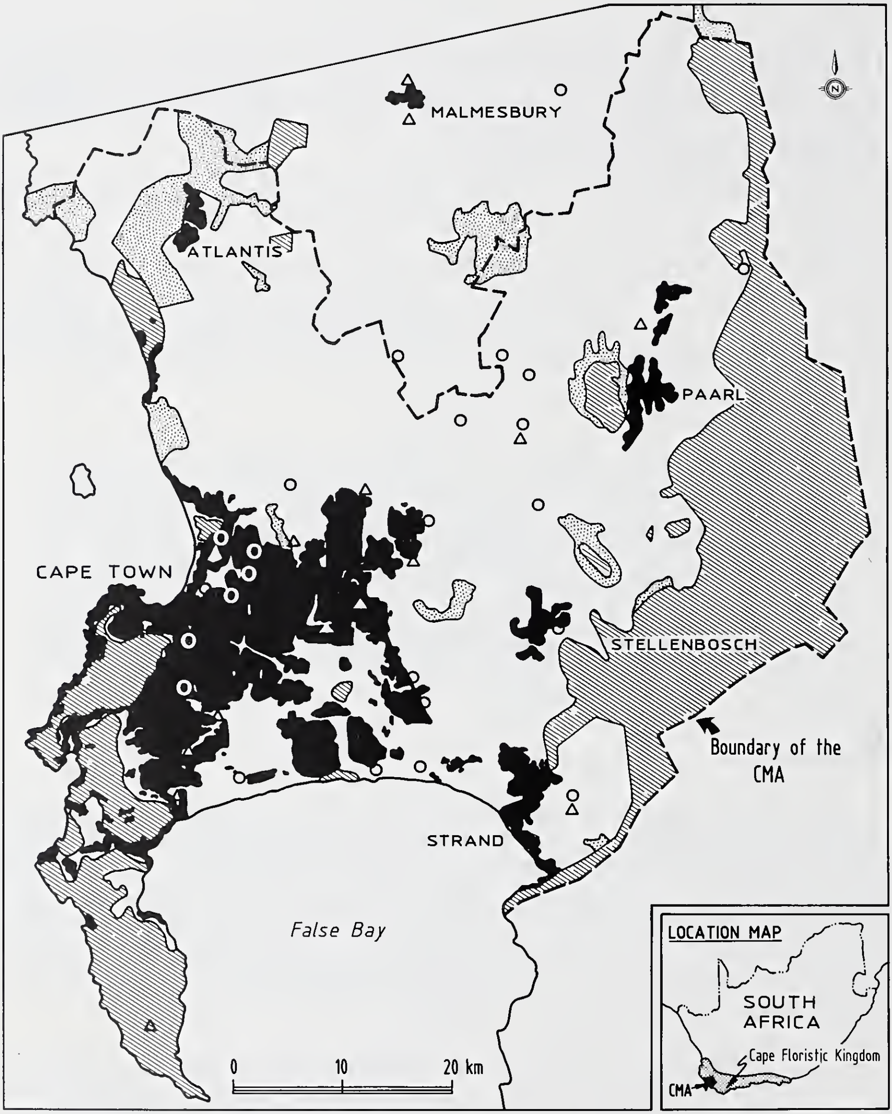

Figure 1.—Location of the large (>100 ha: hatched) and small (<100 ha: open triangles) existing conservation areas in the CMA, and proposed large (>100 ha: stippled) and small (<100 ha: open circles) conservation areas (Daines & Low 1993; Jarman 1986; McDowell & Low 1990). The existing urban areas are shown in black. The inset shows the location of the CMA in South Africa. With the exception of the coastal areas near Atlantis, all the large conservation areas are in mountain fynbos.

Rebelo & Siegfried 1990). Similarly, numbers of *Red data book* species of butterflies, amphibians and reptiles are the highest in the southwest of South Africa, centred on the Cape Peninsula and adjacent lowlands (Rebelo 1992a). Many of these species are concentrated on the Cape Flats, which have been identified as one of the main conservation priorities in the CFR (Rebelo 1992a; Rebelo & Siegfried 1992; Rebelo & Tansley 1993).

Any future development of the urban metropolis within the CFR poses obvious problems for conservation and requires careful planning to avoid the total extermination of endemic species and characteristic vegetation types. Consequently, it is vital to assess the threat to conservation posed by urban development in the CMA, particularly on the Cape Flats, and to identify possible areas of conflict between future development and conservation plans. This paper summarizes and documents available data on floral diversity and urban expansion in the CMA with a view to illustrating the urgency of appropriate action if the biodiversity of this region is to be conserved. Taking into account the available information, this paper is biased towards species, particularly towards numbers of rare and threatened species and loss in area of habitat. The long-term effects of fragmentation on the viability of populations in the CMA are more difficult to document and beyond the scope of this paper.

PHYSICAL AND NATURAL ENVIRONMENT OF THE CMA

The entire CMA is contained within an area bounded by the Hottentots Holland Mountain Range in the east, the Indian Ocean in the south and the Atlantic Ocean in the west. The area incorporates three major physiographic features, i.e. the Cape Peninsula Mountain Chain (hereafter referred to as the Cape Peninsula), an extensive region of low elevation known as the Cape Flats and a series of undulating hills and flat plains to the north in the Darling/Dassenberg area (Figure 2). The diverse topography, coupled with variations in geology and soil type has contributed to the establishment of several characteristic vegetation types (Figure 2). On the Cape Peninsula the dominant vegetation is mountain fynbos, while on the Cape Flats and in the Darling/Dassenberg area sand plain fynbos and strandveld predominate. Within the Darling/Dassenberg area certain of the hills are covered by West Coast renosterveld. To date Cowling & Holmes (1992) have reclassified, based on Campbell (1985), the above-mentioned vegetation types. However, for the purposes of this paper, it was decided not to update the classification, as many of the statistics used (e.g. McDowell *et al.* 1991) were based on the vegetation types previously described by Moll *et al.* (1984).

The Cape Peninsula, the Cape Flats and the Darling/Dassenberg areas have been identified as three distinct centres of diversity and endemism (Figure 2; Daines & Low 1993; Hall & Veldhuis 1985; McDowell *et al.* 1991; McDowell & Low 1990; Rebelo 1992a; Rebelo & Tansley 1993; T. Trinder-Smith pers. comm.). (Although there are no published data on the numbers of endemic taxa in the Darling/Dassenberg centre, recent surveys suggest that the figure far exceeds

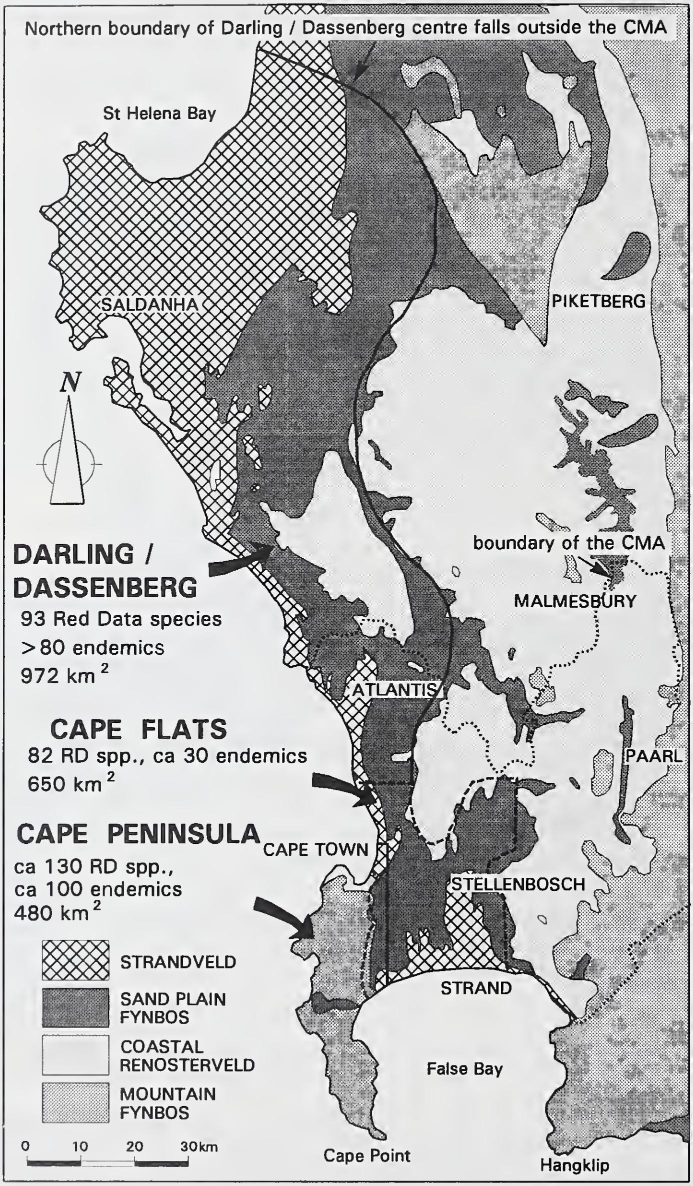

Figure 2.—Centres of endemism in the CMA: the Cape Peninsula, the Cape Flats and the Darling/Dassenberg area.

the 80 taxa which were recorded by Daines & Low (1994) for a smaller area on the West Coast.)

CONSEQUENCES OF URBANIZATION

The CMA has been inhabited since at least 21 000 BP, but formal urban development and settled agriculture began only after the arrival of European settlers in 1652 (Elphick 1985). Extensive urban development in the CMA, particularly on the Cape Flats, has taken place mostly over the last 40 years and has intensified during the last 10 years (City Planner's Department 1993; McDowell *et al.* 1991). The current extent of urbanization is shown in Figure 1.

Main vegetation types affected

Urban expansion has occurred mainly on the Cape Flats, resulting in a marked reduction of the two dominant vegetation types in that area, i.e. sand plain fynbos and strandveld (Figure 2). Sand plain fynbos is restricted to acid sands which cover approximately 62% of the Cape Flats. These sandy areas have been preferred for building sites because they are flat, provide an adequate supply of

Figure 3.—Aerial photograph of an area on the Cape Flats which was originally sand plain fynbos. This flat area, devoid of bedrock and near the centre of Cape Town, was found to be suitable for building. Note the lack of open natural areas.

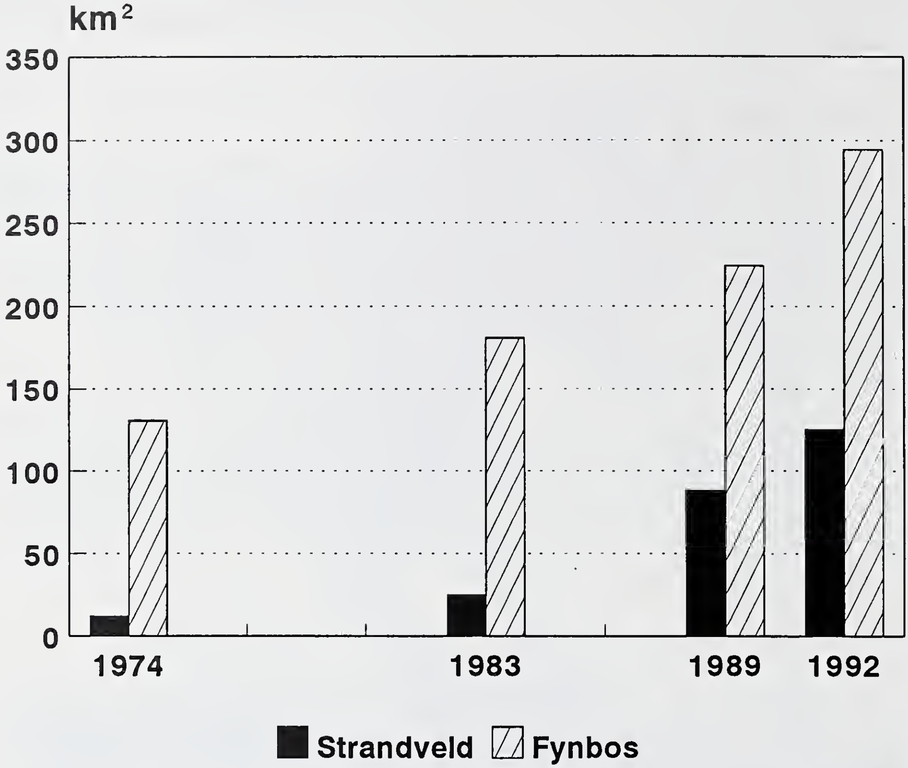

Figure 4.—Amount of natural vegetation converted to urban housing on the Cape Flats during the period 1974–1992. Natural vegetation is divided into the two major vegetation types affected, i.e. sand plain fynbos and strandveld. (The area transformed from fynbos in 1974 is an estimate based on urban trends.)

building sand, and are devoid of bedrock (Figure 3; McDowell *et al.* 1991). By 1983, 45.2% of the original area occupied by sand plain fynbos had been developed (Figure 4; McDowell *et al.* 1991). In contrast, strandveld is restricted to alkaline dune sands which cover about 38% of the Cape Flats. The location of these dune sands away from the existing nodes of development, as well as the nature of the dunefield, initially made these areas less desirable for urban development. Consequently, it is estimated that by 1974 only 5% of strandveld vegetation had been destroyed through urban development, rising to about 10% by 1983 (McDowell *et al.* 1991). However, after 1983, vast areas of strandveld were transformed by developments such as Khayelitsha and the expansion of Mitchell's Plain [Figure 4; McDowell & Low 1990; McDowell *et al.* 1991; see case study (1)]. The destruction of strandveld due to the conversion of dunefields to

housing development was further facilitated by the advancement of dune-grading technology (McDowell *et al.* 1991), which aided developers to level areas previously not suitable for housing.

By 1992, 52% of the original extent of strandveld and 73% of sand plain fynbos on the Cape Flats had been destroyed by urban development (Figure 4). Other factors have also led to the destruction and degradation of natural vegetation so that the cumulative effects of urbanization, agriculture and woody alien infestations have resulted in only 4.84 km^2 of relatively undisturbed sand plain fynbos on the Cape Flats remaining. This amounts to about 1.2% of the original extent of this vegetation type (Figure 5; McDowell *et al.* 1991). Most of the fynbos remnants are concentrated in racecourses, military zones, powerlines and road verges, with very little preserved successfully in formal conservation areas (Figures 6 & 7; McDowell *et al.* 1991). The uncertain future of informal, as well as formal reserve areas [see case study (2)] indicates that the conservation of existing natural habitats is not yet assured.

Of the strandveld not transformed by urban development, only 32% of the original extent is relatively undisturbed natural vegetation. About 10% is under alien invasion (J. Wood & A.B. Low pers. obs.) and 6% has been cleared for cultivated lands (Figure 5).

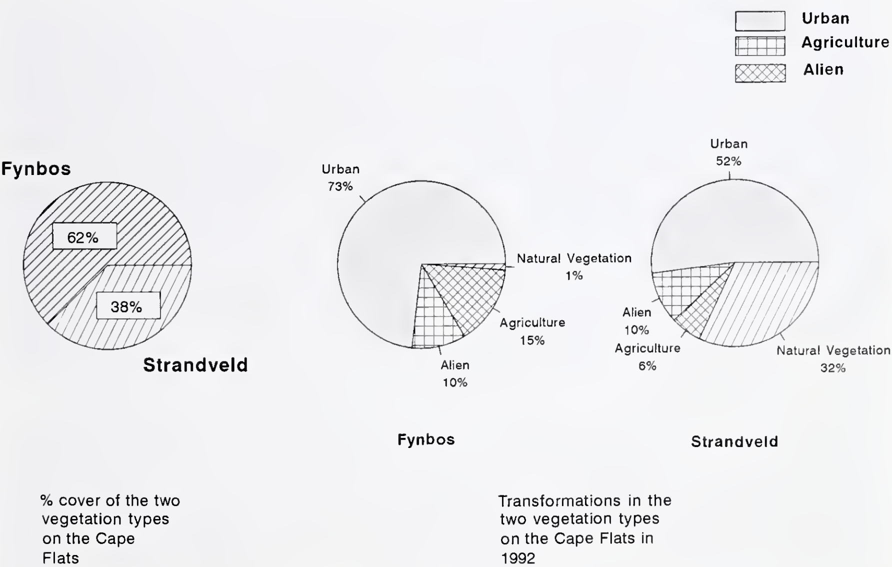

Figure 5.—The percentage of original vegetation within the CMA affected by urbanization, agriculture and alien infestations.

Figure 6.—Sand plain fynbos remnant on Rondebosch Common, Cape Flats.

Loss of species

The process of urbanization has resulted in the fragmentation of previously intact natural environments. Fragmentation leads to the potential loss of habitat for some species and the isolation of other species on natural remnants within an urban environment. It is estimated that fragmentation due to urbanization in the CMA has already caused the extinction of at least five plant species and the local extinction (i.e. extinction of a species in the CMA part of its range) of more than 15 species (McDowell & Low 1990). The extent to which these extinctions are due to the direct effects of habitat destruction by urbanization, to alien infestations or to the more subtle effects influencing remnant vegetation has yet to be ascertained.

The process of fragmentation also leads to the concentration of surviving endemic or threatened species in natural remnants. For instance, it is estimated that there are 15.3 *Red data* species/km^2 in the remnants of sand plain fynbos. This estimate is based on the figure of 74 *Red data* plant taxa which are recorded in the remaining 4.8 km^2 of sand plain fynbos (McDowell *et al.* 1991). This represents one of the highest concentrations of taxa threatened with extinction recorded for Africa, if not for the whole world (with the exception of islands) (McDowell *et al.* 1991). Similarly, of the 26 endemics on the Cape Flats, four occur

in strandveld and 22 in fynbos, giving a value of 4.96 endemic species/km^2 in fynbos remnants (McDowell & Low 1990).

The survival of these threatened and endemic species in corridors and isolated remnants might be questionable as data on the long-term viability of these areas for preserving biodiversity are lacking for the Cape Floristic Region (Rebelo 1992b). However, much evidence is available on the proven high incidence of narrow endemics in the Cape flora (Cowling 1987; Cowling *et al.* 1992; Goldblatt 1978; Raven & Axelrod 1978). Therefore small natural areas might be able to maintain the ecological processes necessary for species survival. To date, available research suggests that with intensive management, areas as small as 6 ha might suffice (Cowling & Bond 1991), but areas closer to 600 ha are required for a viable reserve which will not lose species over time (Bond *et al.* 1988). However, these studies were done elsewhere in fynbos and may not be applicable to lowland fynbos remnants in an urban setting. There are probably few long-term viable populations of many Cape Flats endemics left within the remnants of the CMA. Research is urgently required to appraise the situation so that meaningful conservation prescriptions can be put forward. Finally, fire is essential for the maintenance of fynbos vegetation, but its use in an urban environment is problematic. Managerial norms and public attitudes will need to be changed.

Figure 7.—Sand plain fynbos remnant in the Plattekloof Natural Heritage Site (an area under a powerline), Cape Flats.

THE FUTURE: INCREASE IN POPULATION AND THEIR NEEDS

Increase in population

The human population in the CMA (excluding Atlantis) is expected to rise from 3.1 million in 1992 to over 4.5 million by the year 2010 (Bridgman *et al.* 1992), a doubling in the 30 year period between 1980 and 2010 with a concomitant increase in the need for housing. It is estimated that by the year 2010, some 265 000 new housing units will be required (City Planner's Department 1993). The extent to which housing developments required to meet this demand will threaten remaining areas of natural vegetation will depend to some degree on the type of housing provided. High-density housing (138 units per ha, e.g. Crossroads) will require only 19 km^2, whereas low-density housing (14 units per ha, e.g. Mitchell's Plain) will require 189 km^2 (City Planner's Department 1993).

According to the Cape Town City Council's Town Planning Branch (City Planner's Department 1993), 194 km^2 land of low environmental quality is currently available for housing in the CMA, which is sufficient to meet even the needs for low-density development. However, the proposed areas for urban expansion include natural stands of both sand plain fynbos [e.g. at Kraaifontein—see case study (3)] and strandveld [e.g. extension of Khayelitsha into the Macassar dune—see case study (1)] communities (Figure 8; City Planner's Department 1993).

Future urban expansion within the Cape Metropolitan Area

Low-density urban sprawl is threatening important natural resources at the urban edge. Pressure for growth up the West Coast threatens the Darling/Dassenberg centre of endemism (⑨, Figure 8) with potentially serious effects on all three vegetation types in this region. Urban development northeast of Cape Town (⑩, Figure 8) could potentially impact on remaining sand plain fynbos vegetation. Development along the False Bay coast, (④, Figure 8) could potentially impact on large tracts of strandveld.

Potential areas of conflict between development and areas of conservation value (City Planner's Department 1993; Jarman 1986) can be ascertained from Figure 1 and Figure 8. Most noteworthy is the high concentration of conservation sites to the north in the Darling/Dassenberg area and to the east towards Paarl, both of which lie directly in the path of the potential urban expansions. Therefore planners need to carefully consider the nature and extent of proposed developments if the remaining natural areas are not to be destroyed. To a certain extent, this ideal might be achieved with the recent Metropolitan Development Framework proposals which identified the importance of natural urban open space in future developments (City Planner's Department 1993). Owing to the metropolitan scale of this study, many of the small remnants in the CMA, which are the sites containing much of the biodiversity in this area, are not reflected on the plans. However, the document recommends that a more detailed examination of open space is necessary to ensure that important smaller resource areas are adequate-

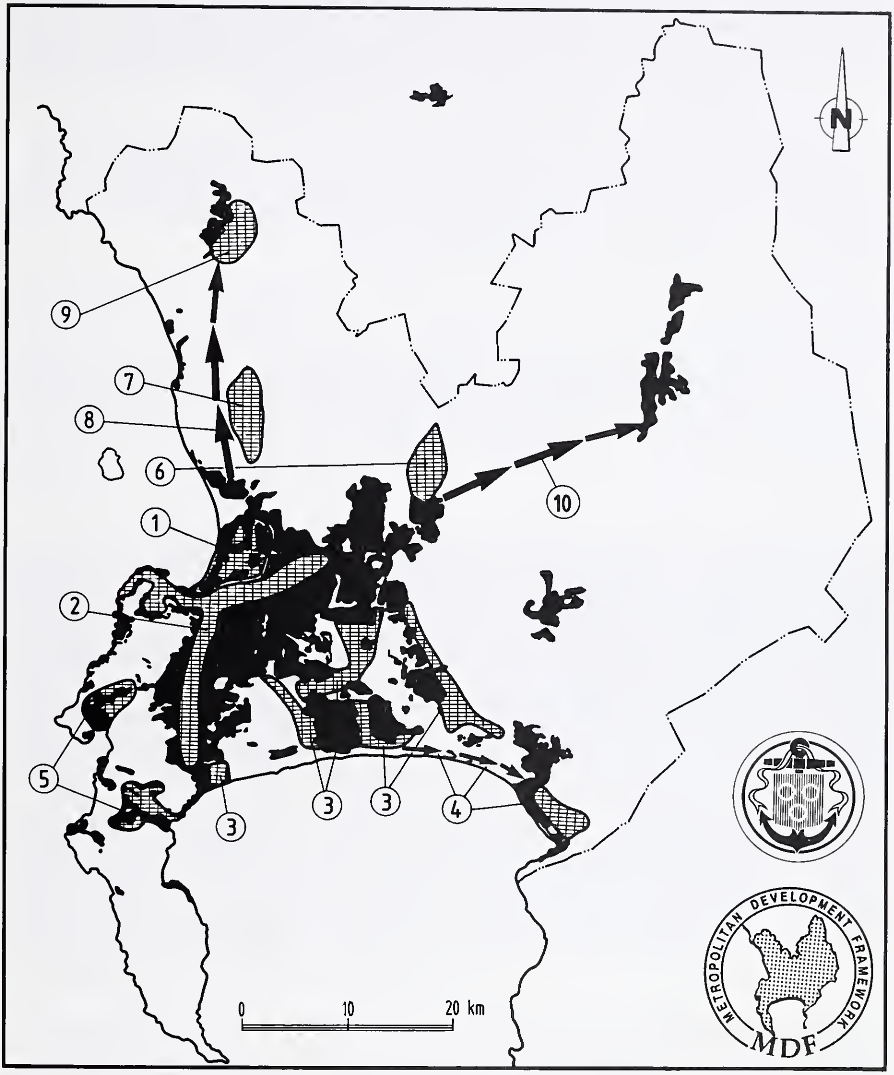

Figure 8.—Possible directions for urban growth within the CMA (a combination of two plans used in document titled *The environmental evaluation for the Cape Metropolitan Area*—City Planner's Department 1993). Growth areas ①–⑦ are regarded as the first phase. ① Develop key sites. ② Densify northern and southern 'spines'. ③ Infill on Cape Flats. ④ Urban expansion from Khayelitsha to Strand. ⑤ Sensitive development in Hout Bay and southern Peninsula. ⑥ Urban expansion north of Kraaifontein. ⑦ Urban expansion on West Coast outside Koeberg high-hazard zone. ⑧ Expand West Coast to Atlantis. ⑨ Expansion at Atlantis possible. ⑩ Expansion between Kraaifontein and Paarl north of and along the N1.

ly protected. Future planning will need to include public participation as a concurrent theme to educate the wider public on the concept of sustainable environments and the value of the floral wealth of the CMA. Community participation and education are particularly relevant in the South African urban context where the social and political milieu faces rapid and dynamic change.

Finally, a positive step in the planning and subsequent implementation of a natural open space plan, which should contribute towards conserving the remaining biodiversity in the CMA, would be the introduction of compulsory IEM (Integrated Environmental Management) procedures.

CASE STUDIES

The issues raised in this paper, namely the loss of biodiversity, poor planning and lack of community participation, are amply illustrated by the following case studies which are all situated on the Cape Flats:

1. Proposed False Bay Coastal Park

This concept of a green open space which allowed for activities such as conservation and recreation was first mentioned in 1982 (Greening the City Report, City Engineer's Department 1982) and its adoption recommended in 1984 (City Engineer's Department 1984). Two years later Jarman (1986) proposed an alternative area further to the east, along the False Bay coast, as a multiple-use area where nature conservation, agriculture, education, recreation and traditional use could be accommodated. This area, 5 450 ha in extent, contained a mix of strandveld on calcareous dunes, coastal fynbos on calcareous sand and limestone, as well as numerous freshwater wetlands. The boundaries extended northwards past Driftsands Nature Reserve, and included the Wolfgat Nature Reserve, Swartklip and the Kuils River inundation area. However, with the rapid expansion of the Khayelitsha urban area, these proposals could not be realized (Figure 1; Jarman 1986; Rebelo 1992a). Settlements such as Khayelitsha were ill-conceived and poorly planned, with no public participation. They were hurriedly developed to deal with the influx of black people who were previously excluded from the area by South Africa's apartheid legislation (Bridgman *et al.* 1992).

The only proclaimed nature reserve in Jarman's (1986) proposed park is Wolfgat (McDowell & Low 1990), which lacks adequate funding for sustainable management and development of infrastructure. Recent pressures on the Reserve from squatting have aroused fears that the conservation status of Wolfgat might be compromised.

2. Drift Sands Nature Reserve

This proclaimed Reserve is the largest on the Cape Flats (± 600 ha), conserving strandveld on calcareous dunes as well as a section of the Kuils River and its

associated wetland habitats. It also forms an important part of the biological corridor that links the northern Cape Flats to the Macassar dunes on the False Bay coast via the Kuils River floodplain. The Kuils River itself is also an important stormwater drainage system (McDowell & Low 1990).

The area forms an important urban open space asset for the major low-income developments of Khayelitsha (in the south), Blue Downs and Mfuleni (to the east) as well as Delft (to the north and west), where an estimated 1.7 million people are likely to be housed (MLH Architects and Planners 1991).

Because of its attributes and location, Driftsands was identified by Low (1991) as an important site for conservation and education and was subsequently included as an important open space area in the environmental evaluation for the Metropolitan Development Framework (City Planner's Department 1993). However, very few attempts were made to promote the image and popularity of the Reserve in the eyes of the public. Nonetheless, local communities in general expressed the need to retain Driftsands as a mixed use environmental area although several saw other issues as being more important (Ngeleza 1990; Nguta 1992).

After a lengthy period of unrest in Crossroads, some 200 people moved illegally into Driftsands in October 1990 and set up an informal settlement along the old national road (Planning Partnership 1993). Due to virtually nonexistent public involvement and lack of promotion of this area as an asset for use by local communities, the authorities were apathetic in dealing with this illegal occupation, and even encouraged the development of a formal settlement. Further problems include the possible siting of a dam to prevent potential flooding of Khayelitsha, mining for sand and a road through the centre of the reserve. All of these are illegal activities in a proclaimed nature reserve.

The Driftsands Task Group was formed in 1989 (Planning Partnership 1993) due to mounting pressures on the Driftsands Nature Reserve for its deproclamation and subsequent rezonation for housing development. Subsequent discussions between the Driftsands Task Group and nature conservation officials revealed a lack of a philosophical basis and intent for conservation areas, including Driftsands, in the CMA. Financial and other resources have been preferably channelled into larger regional reserves.

Various meetings with interested and affected parties led to a compromise whereby the Reserve would become a multiple-use green area, serving a variety of purposes including market and traditional plant gardening, alien woodlots, traditional initiation, nature conservation, education and recreation. A formal settlement of finite size would be developed at the existing site. With this in mind, a structure plan was drawn up by Planning Partnership (1993). However, as yet, certain of the agreements reached have not been effected. Key concerns are:

1. The inability of the authorities to set up a proposed Advisory Committee which would monitor and regulate development of the area.

2. Planning and illegal siting of a residential component in a provincial Nature Reserve without prior discussion or redrawing of Reserve boundaries.

3. The containment of this residential component.

4. The participative input from a wide spectrum of the community and other organizations.

3. Kraaifontein Forest Reserve

This area contains fynbos on deep acid sands with some remnants of renosterveld. This site, 1.4 km^2 in extent, contained the second largest number of threatened plants recorded from any remnant on the Cape Flats, as well as a large number of endemic species (McDowell & Low 1990). It was also identified by Low (1991) as being of exceptional botanical significance.

In 1993 the Botanical Society, after repeated contact with the relevant authorities and various administrative bodies in connection with the possibility of conserving the site, was assured that it would be consulted in the planning process and would form part of an IEM before any development took place (Beaumont 1993). Nevertheless, in April 1993 most of the area was destroyed by the Cape Provincial Administration Roads and Traffic Branch supposedly to clear the area to prevent flooding of the Bloekombos squatter camp. However, there appears to be little justification for the action.

At present a structure plan is being drawn up for the area, which does include some provision for nature conservation in the small remaining naturally vegetated area (A. Beaumont pers. comm.).

CONCLUSIONS

The high concentration of endemic and rare taxa, coupled with the burgeoning population increase in the CMA, emphasizes the need for careful planning to preserve the biotic diversity within this region (Poynton & Roberts 1985; Rebelo 1992b; Rebelo & Tansley 1993). Of the three centres of endemism in the CMA, the vegetation of the Cape Flats has been almost totally destroyed by urbanization, although both alien infestations and agriculture have also played a role. Unlike the Cape Peninsula Mountain Chain which is reasonably well conserved in the Cape Peninsula Protected Natural Area, it is the Cape Flats and other lowlands adjacent to Cape Town, which require immediate attention.

Integral to any proposed plan and subsequent action is the introduction of IEM principles, with particular emphasis on public participation. At the same time, local communities and government should be lobbied and informed on the sensitive nature of the environment and the conservation requirements. On the other hand, conservationists need to determine which areas still retain viable populations of

threatened species and where viable conservation reserves can be established. However, until such information is available, the approach should embody the view that natural remnants in the CMA are pivotal to the conservation of biodiversity, while at the same time being irreplaceable assets for education, recreation, traditional plant use and tourism.

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Disturbance and the diversity of forests in Natal, South Africa: lessons for their utilization

D.A. EVERARD*, G.F. VAN WYK** and J.J. MIDGLEY***

* Division of Forest Science and Technology, CSIR, P.O. Box 395, Pretoria, 0001 South Africa.
** Division of Forest Science and Technology, CSIR, Futululu F.R.S., Private Bag X7066, Mtubatuba, 3935 South Africa.
*** Department of Botany, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

ABSTRACT

The present conservation status of forest patches in Natal, South Africa, is being questioned because few benefits accrue to local rural people and it appears that species are being lost through present 'noninterference' management. By classifying forests according to grain which essentially reflects the scale of disturbance within a forest and by relating this to a measure of beta diversity, we show that disturbance and diversity are related. In order to conserve both biodiversity and the forests, appropriate disturbance regimes should be included in the management of these patches. We suggest that there are ways of incorporating utilization with management which will result in levels of disturbance required to maintain diversity while simultaneously providing some products of value to rural populations.

INTRODUCTION

The numerous patches of indigenous forest which are scattered throughout the province of Natal on the eastern seaboard of South Africa cover an area of approximately 100 000 hectares. This represents only about 1.05% of the total surface area of the province (Cooper 1985), which appears to indicate that they are relatively unimportant. These forests are, however, very diverse and therefore have a high conservation priority. At present, most indigenous forest patches in South Africa are strictly protected and are managed as conservation areas. Although this conservation policy has been extremely successful in preserving the forest patches, it is now being questioned on the grounds that:

1. The forests were traditionally a source of a variety of resources such as poles, sticks, laths, medicines, food, water and grazing for rural populations who now derive few benefits from the protected forest reserves. The forests may therefore be perceived to be of little value to surrounding populations under their present protective management regime, and this could put their future in jeopardy.

2. Although forest patches are preserved, it has been noticed that some processes such as the regeneration of canopy species are not occurring in some patches. This begs the question of whether the forests are being effectively managed for biodiversity maintenance.

A need has arisen to reassess the conservation and management of the forest patches with the potential aim of utilizing resources on a sustainable basis.

Most of the literature on these forests is descriptive, with little information on possible mechanisms involved in the dynamics of the forest communities. For instance, there is very little information on disturbance regimes in the forests or on the life histories of constituent species. This lack of information on forest processes in Natal makes it very difficult to know what level of utilization is sustainable. This prompted us to develop a framework of forest dynamics which could act as a starting point for understanding what levels of utilization might be sustainable (Everard 1992). Our aim was to synthesize data collected for descriptive studies into a dynamics framework. In this approach we used the concept of forest grain (Midgley *et al.* 1990) which reflects the scale of dynamic processes within forest communities. Dynamic processes are usually associated with some form of disturbance. In this paper we present evidence for a relationship between disturbance and diversity and argue that if natural biodiversity is to be successfully conserved, management must include appropriate disturbance. We discuss the potential of integrating disturbance processes with the sustainable utilization of forest resources.

STUDY AREA

The indigenous forests of Natal, South Africa, have been broadly classified into two types: the Afromontane forests (White 1978) of the uplands, and the lowland subtropical forest of the Indian Ocean coastal belt (Moll & White 1978). These two main forest types have been subdivided into a further eight subtypes (Cooper 1985; Edwards 1967; Moll 1978; White 1978). These are the Montane *Podocarpus* Forests and the Mist Belt Mixed *Podocarpus* Forests which are Afromontane, and the Coast Scarp Forest, Coastal Lowlands Forest, Sand Forest, Swamp Forest, Riverine Forest and Dune Forest which are lowland subtropical types. We were able to use data from the following five forest types: Montane *Podocarpus* Forest in the Natal Drakensberg, Mistbelt Mixed *Podocarpus* Forest (Ngome, Hlabeni complex and Weza complex), Coastal Lowlands Forest (Dukuduku), Dune Forest from the Natal south coast (Yengele) and the Natal north coast (Mapelane) and Sand Forest in northern Zululand.

These forests stretch from the coast to the mountains in the interior and thus range from sea level to 2 000 m. Climatic conditions vary considerably along this altitudinal gradient, with temperature being the most significant variable. All forested areas receive at least 800 mm of rainfall annually. The highlands experience temperate conditions while the climate of the coastal areas is subtropical.

This variation in abiotic environmental features accounts for the large floristic differences between the various forest types.

METHODS

Sampling methods

All the plot data were recorded from standard 0.04 ha circular plots (radius = 11.25 m) which were randomly located in mature 'homogeneous' stands of forest. As far as possible, similar communities were sampled within each forest type. The height of all woody species above knee height (0.5 m) was estimated and recorded. The diameter at breast height (DBH) of all woody species with DBH > 50 mm, was also measured and recorded. In each plot note was also taken of the general appearance of the forest, and estimates of canopy, shrub and ground layer height, and the percentage cover of these layers were made and recorded.

Diversity

Standard species richness and species diversity indices [species richness index (d), and Simpson's index (c) (Odum 1983)] were calculated using the plot data. Only woody species were included as some of the data did not include nonwoody herbaceous vegetation. Species richness and the diversity of forest types were then compared.

A measure of beta diversity of the various forest types and patches was obtained by ordinating each forest individually. The variance in the data was displayed on the ordination axes: the more dispersed the plots were on the ordination axes, the greater was the variation within the forest type. This variation between the plots could therefore be used as a measure of beta diversity. We used the eigenvalues of the first axes of the individual ordinations as a measure of beta diversity. By relating the measure of beta diversity with a measure of grain through regression analysis, we were able to investigate the relationship between the diversity of the forest types and the scale of disturbance or grain of the forest types.

Disturbance

Disturbance is extremely difficult to measure in forest vegetation. The reason for this is twofold. First, the frequency of certain disturbances is low and second, the effects of the disturbance on forest composition and structure can be very long lasting. We therefore inferred the scale of disturbance in the forest types by classifying the forests according to grain (sensu Everard 1992).

The grain of a forest community was established from the available plot data using two analyses. First, the composition of the canopy was compared with that of the subcanopy and shrub layer. In a fine-grained forest, one would expect to

find that most of the species occupying the canopy are also present in the subcanopy. These species would recruit from advanced regeneration and would be relatively shade-tolerant. The scale of variation from patch to patch in this type of forest would be small and would therefore exhibit a fine grain. Midgley *et al.* (1990) used this approach to show that Afromontane forests of southern Cape plateaus in South Africa are fine-grained.

The second approach was to analyse the size-class structure of the important tree species in each community. In a fine-grained forest one would expect to find that most trees have an inverse J-shaped curved size-class distribution. In other words, there should be many small trees and few large ones. In more coarse-grained forests the size-class distributions of various species would differ according to their position on the hierarchy of competition for light (degree of shade tolerance). Light-demanding species which will survive only in gaps, would exhibit unimodal or bimodal bell-shaped curves. It is therefore important that the size-class distributions within plots are assessed to see whether large and small trees of the same species co-occur or not. For this analysis we graphed size-class

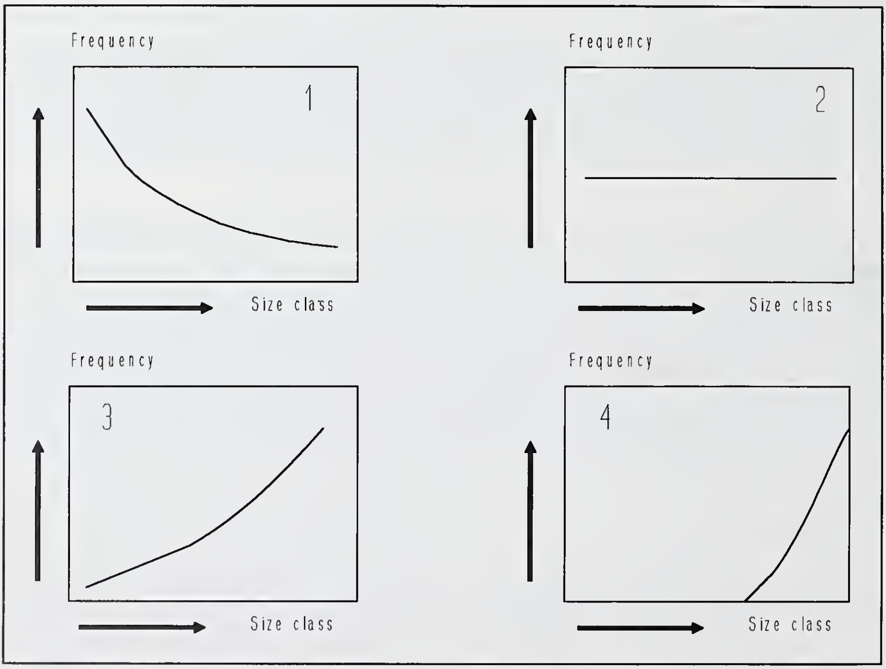

Figure 1.—Four types of size-class distributions. Type 1 has much regeneration with a few mature specimens in the canopy (typical inverse J-shaped curve). Type 2 has equal amounts of regenerating to mature specimens. Type 3 has few regenerating individuals but many individuals in the canopy. The fourth type has many large canopy specimens, but no regeneration.

distributions of the ten most dominant canopy tree species for each forest. The resulting distributions were inspected visually and categorized into four size distribution classes ranging from inverse J (1) to unimodal (4) (Figure 1).

The relationship between grain or disturbance and beta diversity was assessed by regression analysis.

RESULTS

Species diversity indices are presented in Table 1. In general the results indicate that the dune forests and other coastal forests (Sand Forest) are the most species rich and have the highest diversity of woody species. Species richness and diversity tend to decrease with increasing altitude with the most species-poor forests being the Afromontane forests in the Drakensberg. Ngome Forest does not appear to fit this general trend as it has high species richness and diversity.

Simpson's index, which is essentially an index of evenness, measures concentration of dominance, giving greater weight to common species. It indicates that the Afromontane and Sand Forests tend to be dominated by a few species with other species being rare, while the Dune Forests have constant mixes of species.

Diversity

Figure 2 presents the ordination diagram for the entire data set. The first axis (eigenvalue = 0.888) separates forests along an altitudinal gradient, while the second axis (eigenvalue = 0.742) separates the coastal forest along a latitudinal gradient.

TABLE 1.—Mean species richness and species diversity indices for various forests and forest types in Natal. The value in brackets indicates the range of indices for a number (usually 10) of plots.

Forest type	Type	Species richness	Species richness index	Simpson's index
Montane *Podocarpus* Forest	Drakensberg	16.5 (11–20)	7.3 (5.3–9.7)	0.225 (0.104–0.515)
Mistbeld Mixed *Podocarpus* Forest	Ngome	26.2 (23–25)	9.8 (8.0–11.5)	0.192 (0.153–0.251)
Mistbelt Mixed *Podocarpus* Forest	Hlabeni complex	19.0 (12–24)	7.9 (5.0–10.6)	0.19 (0.127–0.265)
Mistbelt Mixed *Podocarpus* Forest	Weza complex	19.6 (11–25)	9.6 (7.6–11.5)	0.153 (0.099–0.258)
Coastal Lowlands Forest	Dukuduku	20.5 (13–28)	10.6 (6.2–12.9)	0.127 (0.069–0.304)
Dune Forest	Yengele	25.6 (14–41)	11.5 (6.9–14.0)	0.091 (0.046–0.269)
Dune Forest	Mapelane	29.8 (22–38)	12.2 (8.4–14.7)	0.125 (0.059–0.189)
Sand Forest	Zululand complex	25.0 (15–38)	9.8 (5.6–14.5)	0.227 (0.091–0.383)

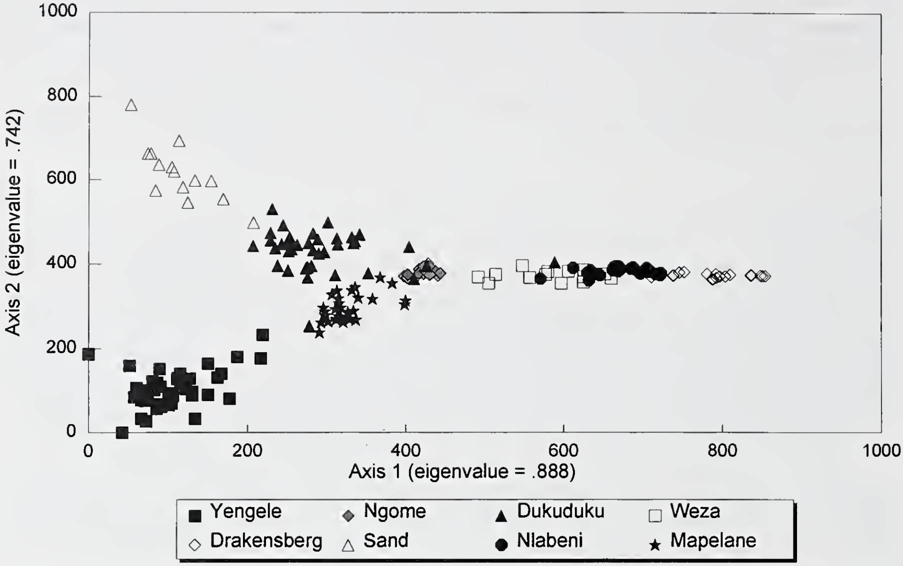

Figure 2.—Scatter diagram showing the ordination by DECORANA of all forest patches together.

Table 2 presents the eigenvalues of the first axes of the individual ordination of the various forest types. These eigenvalues are considered to be a measure of beta diversity as data sets which have little separation of species along the axes produce low eigenvalues, while high eigenvalues are obtained from a good separation of species along the respective axes (Jongman *et al.* 1987).

TABLE 2.—The eigenvalue for axis 1 of ordinations of each forest type. The variation in species composition between the plots is related to the eigenvalue obtained; therefore a high eigenvalue indicates large variations in species and a low eigenvalue indicates little variation in species between plots. Hence the eigenvalue is related to beta diversity.

Forest type	Forest	Eigenvalue
Montane *Podocarpus* Forest	Drakensberg	0.44
Mistbelt Mixed *Podocarpus* Forest	Ngome	0.23
Mistbelt Mixed *Podocarpus* Forest	Hlabeni complex	0.24
Mistbelt Mixed *Podocarpus* Forest	Weza complex	0.46
Coastal Lowlands Forest	Dukuduku	0.58
Dune Forest	Yengele	0.39
Dune Forest	Mapelane	0.34
Sand Forest	Zululand	0.31

TABLE 3.—Mean distances (ordination units) between samples with subcanopy/shrub composition and canopy composition from the same plots

Forest type	Forest	Mean distance (ordination units)
Montane *Podocarpus* Forest	Drakensberg	62.3
Mistbelt Mixed *Podocarpus* Forest	Ngome	19.5
Mistbelt Mixed *Podocarpus* Forest	Hlabeni complex	36.2
Mistbelt Mixed *Podocarpus* Forest	Weza complex	47.4
Coastal Lowlands Forest	Dukuduku	85.6
Dune Forest	Yengele	42.7
Dune Forest	Mapelane	31.0
Sand Forest	Zululand	37.1

Grain

The grain of the forest patches was established by interpreting the ordination comprising the canopy versus the subcanopy (Table 3) in conjunction with the size-class distributions of the common tree species (Table 4).

Our results indicate that the forests can be differentiated and classified according to grain. Forests with a high proportion of trees which show unimodally distributed size-class distributions (class 4) generally also have large differences in ordination units between canopy and subcanopy strata. The finest-grained forest appears to be Ngome Forest which is a Mistbelt Mixed *Podocarpus* Forest. The gradient in grain continues from the relatively fine-grained Dune Forests, through the relatively coarse-grained Afromontane *Podocarpus* Forest to the very coarse-grained Coastal Lowlands Forests.

Disturbance vs diversity

Figure 3 shows the measure of grain (Table 3) of the forest types plotted against the measures of beta diversity (Table 2). The regression line which has

TABLE 4.—Frequency of curve type for the size-class distributions of the ten dominant canopy species found in the various forest types. The four classes are explained in Figure 1.

Forest type	Forest	Frequencies of curve types for size-class distributions 1 2 3 4
Montane *Podocarpus* Forest	Drakensberg	1 4 1 3
Mistbelt Mixed *Podocarpus* Forest	Ngome	6 3 0 1
Mistbelt Mixed *Podocarpus* Forest	Hlabeni complex	3 4 0 3
Mistbelt Mixed *Podocarpus* Forest	Weza complex	2 2 2 4
Coastal Lowlands Forest	Dukuduku	1 3 2 4
Dune Forest	Yengele	5 4 0 1
Dune Forest	Mapelane	5 2 2 1
Sand Forest	Zululand	3 0 3 4

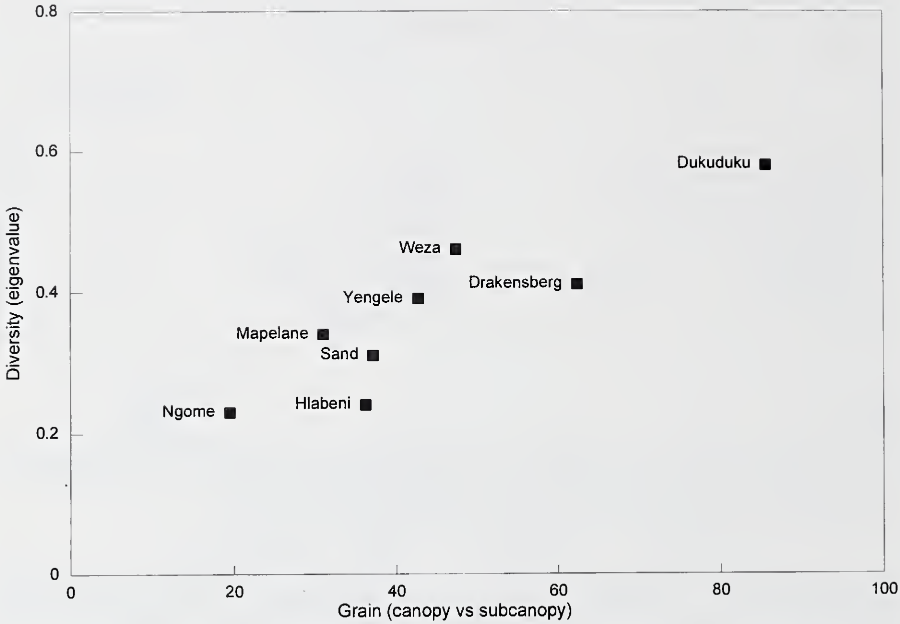

Figure 3.—Measure of grain plotted against a measure of beta diversity for each forest patch.

been included, indicates a very strong relationship ($r = 0.89$) between beta diversity and grain, which implies that there is a relationship between the scale of disturbance and diversity.

DISCUSSION

The floristic composition of the forests in Natal is reasonably well known and has been used to classify the forests into distinctive types (Everard 1991). The classification of the forest types according to grain indicates that there is a variation of grain between forest types. The comparison of the canopy layer with the subcanopy layer shows that Ngome Forest, a Mistbelt Mixed *Podocarpus* Forest, has the most similar strata. The Montane *Podocarpus* Forests in the Drakensberg and both Dune Forests studied, were shown to be intermediately grained, with the canopy and subcanopy showing greater differences than the Mistbelt Mixed *Podocarpus* Forests. The size-class distributions of the common species also showed that some of the species have a bell-shaped curve indicating fewer small individuals than large individuals, though most have an inverse J-shaped curve. Coastal Lowlands Forest showed the greatest variation between the canopy and the subcanopy layers and is classified as coarse-grained. Everard (1992) presents detailed methods and the principles underlying the concept of grain and

explores the relationship between grain (structure) and dynamics within the forest vegetation.

In the event of a gap forming and thereby causing disturbance, a number of scenarios can occur. A fast growing, shade-intolerant species could quickly colonize the gap and grow up to become part of the canopy; or the existing shade-tolerant species could dominate and close the gap or, lastly, the gap could be closed laterally by trees in the existing canopy. In fine-grained forests most of the common canopy species appeared to be shade-tolerant, recruitment appears therefore to be predominantly by growth of existing, shade-tolerant species. In coarse-grained forest the canopy is dominated by shade-intolerant species; it therefore appears that recruitment occurs predominantly by colonization and rapid growth of shade-intolerant species.

The interpretation of the relationship between grain and disturbance is based on the observation that the fine-grained forests are dominated by shade-tolerant species and the coarse-grained forests by shade-intolerant species. Shade-tolerant species regenerate under a relatively closed canopy and are able to persist under the canopy, and therefore do not require disturbance to become established in a forest. A fine-grained forest would therefore not require high levels of disturbance. Coarse-grained forests have more shade-intolerant species in the canopy and in the absence of disturbance these species tend to be rare in the subcanopy layers. It is therefore assumed that coarse-grained forests require disturbance to regenerate. The scale of disturbance is predicted to influence the coarseness of the grain, with large-scale disturbance (relatively frequent gaps of between 100 m^2 and 10 000 m^2) resulting in coarse-grained forests.

There is a strong relationship between the grain of a forest and the variation (beta diversity) within a forest type (Figure 3). This essentially implies that diversity is related to disturbance and that appropriate disturbance regimes are required to maintain diversity. For example, in the Coastal Lowlands Forest most canopy dominants are shade-intolerant species, which require a relatively large-scale disturbance to regenerate. Van Wyk & Everard (1993) have shown that in the absence of disturbance this forest tends to become more fine-grained with the loss of species (Table 5). This forest type, therefore, requires periodic large-scale

TABLE 5.—Frequency of the size-class distribution types of the ten dominant species in three communities within the Dukuduku Forest. These communities occur along a successional gradient, with the peripheral core forests at the earlier stage and the inner core forest at the other end of the gradient. Size-class distribution types are the same as those shown in Figure 1.

Forest community	Total number of tree species	Frequencies of curve types for size-class distributions 1 2 3 4
Peripheral core forests	51	1 2 3 4
Central core forests	48	3 2 2 3
Inner core forests	34	5 1 1 3

disturbances to maintain current species composition and level of diversity. Fine-grained forests on the other hand, do not need large-scale disturbance to maintain species diversity.

Lessons for utilization

We have argued that to maintain forest diversity, appropriate disturbance is required. Rural populations surrounding the many forest patches need to receive some benefit from these forests, should these be conserved in the future. By matching the requirements of the forests for various forms of disturbance with the requirements for resources by surrounding populations, the future conservation of the forests and the biodiversity contained in them will be more likely. One of the most important products required by rural populations from forests is poles. Fine-grained forests generally have a huge supply of poles of most species and the exploitation of this resource, if managed appropriately, would probably have very little effect on the long-term composition of the forest. In coarser-grained forests, the supply of poles might be confined to the shade-tolerant species which grow in the understorey in abundance. If poles of shade-intolerant species were exploited in gaps, these species could be lost to the forest as they are restricted to gaps and generally are not abundant. In coarse-grained forests it might be necessary to allow an occasional large-scale disturbance to occur in the forest, where a number of trees are removed to create a large gap. Utilization in such a forest would be intense in small areas, with very long recovery times thus mimicking the occasional large-scale disturbance processes under which the forest developed.

We therefore advocate that forest management must include a range of management practices, from extensive sustainable utilization to total protection of parts of a forest. Such management will ensure that all stages of forest development (early successional stages to ‘old growth’ stages) are maintained, thereby conserving forest biodiversity.

CONCLUSIONS

It is evident that not only do forests in Natal differ in composition, but they also differ in their grain which reflects the dynamic ecological processes maintaining them. These processes occur at various scales and are related to disturbance. There also appears to be a relationship between disturbance and the diversity of forest types. We argue that disturbance within forest patches is essential for the maintenance of diversity because in the absence of disturbance, the shade-intolerant species will be reduced. We suggest that incorporating disturbance management with utilization would help with the conservation of the forests. We emphasize, however, that knowledge of forest processes is lacking and that much work needs to be done to match sustained utilization with natural forest dynamics.

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The conservation status of Aloaceae in southern Africa

C. HILTON-TAYLOR* and G.F. SMITH**

* Conservation Biology Research Unit, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

** National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

ABSTRACT

Since their introduction into European horticulture, species of Aloaceae have fascinated professional taxonomists and amateur botanists alike. Alooid species have remained popular amongst specialist collectors as well as in amenity and commercial horticulture, and specimens are offered for sale as far afield as Japan and the United States of America. This demand, together with regional agricultural and urban development, has lead to extensive pressure on the wild populations of some alooid species. This paper reviews the conservation status of the family Aloaceae with reference to its ecological value in southern Africa, and provides an updated Red Data List for the family. It is shown that 31% of the taxa of southern African Aloaceae are threatened to some degree, with the major alooid genera, *Aloe* and *Haworthia*, having 49 and 40 threatened taxa respectively. Generalized conservation management strategies are proposed for the family as a whole.

INTRODUCTION

Although distributed through a large part of the Old World, the Aloaceae, a fairly small family of monocots, has its major centre, both in evolutionary terms and in total number of species and genera, in southern Africa. Of the approximately 436 species in some seven genera in the family, there are about 233 species in six genera in the area covered by the *Flora of southern Africa* (*FSA*) project. This research programme was initiated by the then Botanical Research Institute, Pretoria, about 30 years ago in order to arrive at a taxonomic account of all known indigenous and naturalized plant taxa of the subcontinent south of, but excluding, Angola, Zambia, Zimbabwe, and Mozambique. In terms of number of species the Aloaceae is the eighteenth largest family in the subcontinent, and the sixth largest monocot family (cf. Table 4 in Goldblatt 1978, and assuming fragmentation of the Liliaceae into several smaller families).

The question of rank and, related to this, the name of the Aloaceae, has been discussed since the early 1800s, as recently summarized by Smith (1993). There is, however, general agreement on the question of familial monophyly; a number of synapomorphies can be listed for the alooid genera (Smith & Van Wyk 1991),

thus confirming their common origin. Even if the alooids are regarded as constituents of the Asphodelaceae, as proposed by Dahlgren *et al.* (1985), the subfamily Alooideae in which they are then included remains a fairly natural group.

In contrast to the Iridaceae, of which more than two thirds of the southern African species occur in the Cape Floristic Region (Goldblatt 1989, 1991), the phytogeographic centre of the major alooid genus, *Aloe* L., cannot be restricted to any one region (Gibbs Russell 1987). However, in southern Africa three major centres of unusually high species density have been identified for the genus (Holland 1978). These are (with the approximate number of species in brackets): the eastern Transvaal, including the dry river valleys of northern Natal (66); the eastern Cape, including Transkei and southern Natal (29); and Namibia, including the western Cape coastal belt (20). The geographical distribution of the family Aloaceae covers most of sub-Saharan Africa, with only three species in West Africa and the remainder in the eastern and southern parts, and with species numbers increasing considerably southwards (Smith & Van Wyk 1991). However, the fleshy fruited genus *Lomatophyllum* Willd. is restricted to Madagascar and a few of the Mascarene islands off the southeast coast of Africa (Robertson 1989; Schill 1973), and species of *Aloe* also occur on the Arabian Peninsula, Madagascar and Socotra (Reynolds 1966). In contrast to the closely related and predominantly southern African Asphodelaceae genera *Bulbine* Wolf and *Bulbinella* Kunth, which also occur in Australia and New Zealand respectively, the family Aloaceae is absent from other austral continents.

The distribution patterns of *Astroloba* Uitewaal, *Gasteria* Duval, and *Haworthia* Duval, closely resemble one another (Smith & Van Wyk 1991). These three genera are largely restricted to the summer-dry, semi-arid coastal regions below the inland escarpment of the subcontinent. *Gasteria* and *Haworthia*, however, have outliers in the arid river valleys of Natal, Swaziland and the eastern Transvaal. *Astroloba* is less widely distributed than *Gasteria* or *Haworthia* and its members are usually found in slightly more arid environments of the Savanna, Fynbos and Succulent Karoo Biomes of southern Africa. These three genera and *Aloe* have relatively large numbers of species indigenous and endemic to the arid Subtropical Transitional Thickets of the eastern Cape (59 species with 41% endemic) where they show signs of active speciation (Smith & Marx 1990). Of all the genera of Aloaceae, the monotypic *Poellnitzia* Uitewaal, has the most restricted distribution. It is endemic to the Robertson and Bonnievale districts of the Worcester-Robertson Karoo in the southwestern Cape (Smith 1994a, 1994b). In contrast, the other monotype, *Chortolirion* A. Berger, is widely distributed in the summer rainfall grasslands of southern Africa (Smith 1994b).

For the entire Aloaceae the level of endemism is high at the species level with about 94% of the species indigenous to southern Africa being endemic to the region (see e.g. Torrance (1988) on *Aloe*). Generic endemism is lower, with two of the seven genera being endemic (*Astroloba*, *Poellnitzia*), and three near-endemic (*Chortolirion*, *Gasteria*, *Haworthia*) to southern Africa. *Chortolirion* also occurs in Angola and Zimbabwe (Smith 1991), while both *Gasteria* (Van Jaarsveld

1992) and *Haworthia* (Marloth 1908–1910) have been reported from Mozambique.

Aloaceae are petaloid monocots, almost all long-lived, rosulate succulents that have above-ground storage organs (leaves, stems), but a few also have subterranean storage and perennating organs (e.g. *Chortolirion*). Very few (e.g. *Aloe buettneri* A. Berger and *A. verecunda* Pole-Evans) are deciduous in the sense that they die down and become dormant for part of the year, usually the cold, dry season. Floral morphology is variable and some basic forms occur repeatedly in different genera; this adds another dimension to the taxonomic interpretation of the patterns of variation (Smith & Van Wyk 1991).

Leaf succulence characterizes all Aloaceae, which vary in growth form from tiny compact plants, sometimes growing sunken into the ground (*Haworthia maughanii* Poelln.), to trees of up to 20 m high (*Aloe barberae* Dyer). Most common though, are small, medium-sized, or tree-like shrubs and solitary plants, which sometimes dominate large areas of the southern African landscape (e.g. *Aloe ferox* Mill. which occurs from the southern Orange Free State to the southwestern Cape). The bright flowers, interesting leaf ornamentation, and the horticultural hardiness of most species of Aloaceae make them attractive for cultivation, even under less favourable hot and dry conditions (Fourie 1984). Although most species are well adapted to arid environments, few can survive low temperatures and frost, and severely cold spells will occasionally lead to the demise of individuals of species that occur naturally on the climatically severe inland escarpment (e.g. *Aloe greatheadii* Schönland var. *davyana* (Schönland) Glen & D.S.Hardy; personal observation by G.F. Smith, although some of these plants may resprout a few weeks later, H.F. Glen pers. comm.). There are some species, however, that appear to be cold-tolerant and frost-resistant (e.g. *Aloe broomii* Schönland, *A. polyphylla* Schönland ex Pillans and *A. pratensis* Baker).

Although species of Aloaceae were introduced to European horticulture in the late 1600s and early 1700s, a major growth of interest in the cultivation of southern African succulent species occurred mainly during the period 1778 to 1830. Following this 'Cape' period in European horticulture (Gunn & Codd 1981), there was a decline in the popularity of the Aloaceae. In recent years, however, there has been a major resurgence of interest, not only amongst Europeans but also amongst North Americans and Japanese, the latter being especially keen on the diminutive *Haworthia* species, particularly those in the subgenus *Haworthia*. South African plant collectors have also shown much interest in the family, particularly during the late 1960s and early '70s when there was considerable demand for species of *Aloe*. Often the demand for some species has far exceeded the supply from the commercial sector and there has subsequently been considerable trade in plants collected illegally from the wild (Oldfield 1987). Unfortunately many Aloaceae species have very restricted distributions and are naturally rare. Hence the increased demand for these species, coupled with expanding agricultural activities, overgrazing by domestic livestock and urban development, has resulted in many of them becoming threatened with extinction in the wild today. This

problem is further exacerbated by the fact that many *Haworthia* species have small island-like populations, each of which is noticeably different in appearance and therefore of interest to the collector. This is in contrast to species of *Aloe* with island-like populations (e.g. *A. haemanthifolia* A. Berger & Marloth and *A. comosa* Marloth & A. Berger) which are very similar in appearance, and are therefore not all affected by collectors. This paper summarizes the present conservation status of the Aloaceae in southern Africa, and proposes a number of measures to ensure the continued preservation of all the taxa.

METHODS

Although it has been proposed that no single theory, hypothesis or definition is sufficient to describe and understand the concept of rarity in plant species (Fiedler 1986), there is increasing evidence that rare species have characteristics that differ from those of taxa that are more common (Kunin & Gaston 1993; Schwartz 1993). The World Conservation Union (IUCN) has developed standard categories which attempt to apply concepts of static and dynamic rarity to threatened taxa (see papers in Fitter & Fitter 1987). Although these codes of rarity and endangerment have been criticized, particularly for being circular and overly subjective (Mace & Lande 1991), the utility value of an international system should not be underestimated. This system is currently under revision (Mace *et al.* 1993), but as the proposed categories are likely to be further modified before final acceptance, it was decided not to use the new criteria and categories here. The current IUCN Red Data categories are widely used in southern Africa, and have become established (with minor modifications) in various publications dealing with the threatened plants of the region (e.g. Fourie 1986; Hall *et al.* 1980; Hall & Veldhuis 1985). For the sake of uniformity, we have used the current IUCN categories as guidelines for assessing the conservation status of the southern African species of Aloaceae. These categories are as follows (Davis *et al.* 1986):

Extinct (Ex): taxa which are no longer known to exist in the wild after repeated searches of their type localities and other known or likely places. This category is also used for a taxon which no longer occurs in the wild but survives in at least some form in cultivation or in a seed bank, but probably so genetically impoverished or altered as to make it impossible to return it to a natural habitat.

Endangered (E): taxa in immediate danger of extinction if the factors causing decline continue operating. Included here are taxa whose numbers of individuals have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction.

Vulnerable (V): taxa believed likely to move into the Endangered category in the near future if the factors causing decline continue operating. Included here are taxa of which most or all of the populations are decreasing because of overexploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate

security is not yet assured; and taxa with populations that are still abundant but are under threat from serious adverse factors throughout their range.

Critically Rare (R): taxa with small world populations that are not at present Endangered or Vulnerable, but are at risk as some unexpected threat could easily cause a critical decline. These taxa are usually localized within restricted geographical areas or habitats or are thinly scattered over a more extensive range. The category is termed Critically Rare to distinguish it from the more generally used word 'rare' (Hall & Veldhuis 1985).

Indeterminate (I): taxa known to be Extinct, Endangered, Vulnerable, or Critically Rare but where there is not enough information to say which of the four categories is appropriate.

Insufficiently Known (K): taxa that are suspected but not definitely known to belong to any of the above categories, because of the lack of information. (Note, most of the South African literature has termed this category 'Uncertain'.)

Not threatened (nt): used for taxa which are no longer in one of the above categories due to an increase in population sizes or to subsequent discoveries of more individuals or populations.

Out of Danger (O): taxa formerly included in one of the above categories, but which are now considered relatively secure because effective conservation measures have been taken, or because the previous threat to their survival has been removed.

Data on the conservation status of species of Aloaceae were obtained primarily from the *Southern African red data book: plants—Succulent and Nama-Karoo Biomes* (Hilton-Taylor in prep.). Additional information was obtained from the Threatened Plant Databases maintained by the various conservation authorities (Cape Nature Conservation: R. Stanvliet; Natal Parks Board: R. Scott-Shaw; Orange Free State Directorate of Nature and Environmental Conservation: J. du Preez; Transvaal Directorate of Nature and Environmental Conservation: W. Boyd; Swaziland National Trust Commission: K. Braun). Various benchmark publications on the threatened plants of specific geographical or political regions also provided invaluable information, particularly on the past conservation status. Apart from the works of Hall *et al.* (1980) and Hall & Veldhuis (1985), these include Everard (1988) on the eastern Cape; Fourie (1986) on the Transvaal; Jankowitz (1975, 1977) and Müller (1985) on Namibia; Kimberley (1971, 1975, 1980, 1992) on Zimbabwe; and the Threatened Plants Database of the World Conservation Monitoring Centre for a regional perspective (WCMC 1993). Much of the above literature unfortunately is out-of-date and therefore had to be complemented with extensive field observations by the authors. In addition, we consulted with various knowledgeable people on the conservation status of doubtfully threatened alooid taxa. These include E.J. van Jaarsveld on *Gasteria* and M.B. Bayer, P.V. Bruyns and J.D. Venter on *Haworthia*. The conservation status assigned to each species was also based on its entire distribution range,

i.e. if a taxon is rare in one political region but common in other areas, it was omitted from the list.

The taxonomy of Aloaceae has received considerable but sporadic attention in the last few decades. Size estimates of the genera vary somewhat and are mainly functions of the revisions upheld. Nomenclature here follows the taxonomic treatments listed in Table 1.

RESULTS

The results of the survey on the conservation status of species of the Aloaceae are given in Tables 2–4. In the case of *Aloe,* the number of threatened taxa has increased from 29 to 49, i.e. 28% of the taxa are under some degree of threat (Tables 2 and 5). About 45% of these occur in the Cape Province, and 30% in the Transvaal. Although many of the taxa have a naturally restricted distribution, succulent plant collectors, injudicious farming practices (particularly overgrazing by domestic livestock), afforestation, mining and urbanization have all contributed to the decline of the sizes of populations of many species.

For *Haworthia*, the number of threatened taxa has increased from 6 to 40, i.e. 35% of all taxa are threatened (Tables 3 and 5). This increase is the result of new information on the genus obtained in the survey of the Karoo by Hilton-Taylor (in prep., see above). Agriculture, particularly ploughing for cereal crops, has contributed substantially to the decline of population sizes, with a number of taxa on the brink of extinction. Desertification through overgrazing also poses a threat to a number of taxa and this could increase if the anticipated land reforms result in a switch to communal grazing practices. Illegal collecting by succulent collectors has also had a marked impact on a number of taxa. The popularity of species of *Haworthia* amongst succulent enthusiasts was probably sparked off by the publication of three major works on the genus in the 1980s (Bayer 1982; Pilbeam 1983; Scott 1985). *Haworthia* species are, however, not all equally sought after, as those in the subgenus *Haworthia* appear to be more popular than those in the

TABLE 1.—Southern African genera of Aloaceae. Species described since the publication of the latest taxonomic treatment of the genus concerned (column 4) have been included, as far as possible, in column 2.

Genus	Approximate no. of taxa	Major vegetation type	Taxonomic treatment
Aloe L.	177	Widespread	Reynolds (1982)
Astroloba Uitewaal	5	Thicket & Succulent Karoo	Groen (1986, 1987)
Chortolirion A. Berger	1	Grassland	Smith (1991)
Gasteria Duval	22	Fynbos & Thicket	Van Jaarsveld (1992)
Haworthia Duval	115	Fynbos & Thicket	Bayer (1982)
Poellnitzia Uitewaal	1	Succulent Karoo	Smith (1994a)
TOTAL	321		

TABLE 2.—Threatened southern African species of *Aloe*. The numbers in the first column represent the subgeneric portion of the numbers by which the taxa are recognized in PRECIS (National Herbarium, Pretoria [**PRE**] **C**omputerized **I**nformation **S**ystem) (Arnold & De Wet 1993). Taxa that lack numbers in the first column are currently included in the synonymy of widespread species. The past conservation status (shown in brackets) is obtained from Everard (1988), Fourie (1986), Hall *et al.* (1980), and Hall & Veldhuis (1985).

No.	Taxon	Region	Conservation status	Reason for decline of species
400	*A. albida* (Stapf) Reynolds	T, S	V (V)	Afforestation
700	*A. angelica* Pole-Evans	T	nt (R)	–
900	*A. arenicola* Reynolds	C	V	Mining; overgrazing
1400	*A. bowiea* Schult. & Schult. f.	C	E	Urbanization; overgrazing
2300	*A. buhrii* Lavranos	C	R (R)	Very localized
2800	*A. chlorantha* Lavranos	C	E	Very localized; insect predation
3500	*A. comosa* Marloth & A. Berger	C	R	Collectors; overgrazing; agriculture
3720	*A. cooperi* Baker subsp. *pulchra* Glen & D.S. Hardy	N, S	K	Very localized
3750	*A. corallina* I. Verd.	A	R	–
3850	*A. dabenorisana* Van Jaarsv.	C	R	Localized; collectors
4200	*A. dewinteri* Giess	A	R	Very localized
4400	*A. dinteri* A. Berger	A	R	–
4500	*A. distans* Haw.	C	R (R)	–
5000	*A. erinacea* D.S. Hardy	A	R (V)	–
5300	*A. falcata* Baker	C	V	Collectors; agriculture
5550	*A. fouriei* D.S. Hardy & Glen	T	K	–
5800	*A. gerstneri* Reynolds	N	R (V)	–
–	(= *A. graciliflora* Groenew.) *A. greatheadii* Schönland var. *davyana* (Schönland) Glen & D.S. Hardy	T	nt (R)	–
6300	*A. gracilis* Haw. var. *decumbens* Reynolds	C	R	Afforestation; agriculture
6700	*A. greenii* Baker	N	nt (R)	–
6800	*A. haemanthifolia* A. Berger & Marloth	C	R	–
6850	*A. hardyi* Glen	T	K	–
–	(= *A. karasbergensis* Pillans) *A. striata* Haw. subsp. *karasbergensis* (Pillans) Glen & D.S.Hardy	C, A	nt (V)	–
8000	*A. keithii* Reynolds	S	R (K)	–
8100	*A. khamiesensis* Pillans	C	K	Collectors
8500	*A. krapohliana* Marloth	C	V	Mining; collectors; overgrazing
9400	*A. longistyla* Baker	C	V	Collectors; overgrazing
9850	*A. meyeri* Van Jaarsv.	C	R	Very localized
9900	*A. microcantha* Haw.	C	R	Urbanization; agriculture
–	(= *A. minima* Baker var. *blyderivierensis* (Groenew.) Reynolds) *A. minima* Baker	T, S, N	nt (R)	–
10400	*A. modesta* Reynolds	T	K (K)	–
10500	*A. monotropa* I. Verd.	T	E (V, E)	–
11600	*A. pearsonii* Schönland	C, A	V	Mining; overgrazing; collectors
11700	*A. peglerae* Schönland	T	R (R)	–
11900	*A. petrophila* Pillans	T	R (R)	–
11950	*A. pictifolia* D.S. Hardy	C	R	Localized
12000	*A. pillansii* L. Guthrie	C, A	E	Overgrazing; collectors
12300	*A. polyphylla* Schönland ex Pillans	L	E (V)	Collectors; dam construction
12400	*A. pratensis* Baker	N, C, L	K	Agriculture; collectors
12600	*A. prinslooi* I. Verd. & D.S. Hardy	N	R (K)	–
12700	*A. pruinosa* Reynolds	N	nt (R)	–
12800	*A. ramosissima* Pillans	C, A	V	Mining; overgrazing
12900	*A. reitzii* Reynolds var. *reitzii*	T	I (K)	–
12950	*A. reitzii* Reynolds var. *vernalis* D.S. Hardy	N	R (K)	Very localized
13000	*A. reynoldsii* Letty	C	V (V)	–
13400	*A. saundersiae* (Reynolds) Reynolds	N	V	Very localized
13600	*A. simii* Pole-Evans	T	V (R,V)	–
13700	*A. sladeniana* Pole-Evans	A	R	–
13800	*A. soutpansbergensis* I. Verd.	T	R (R)	–
14090	*A. striata* Haw. subsp. *komaggasensis* (Kritzinger & Van Jaarsv.) Glen & D.S. Hardy	C	R	Localized; collectors; overgrazing
14500	*A. suffulta* Reynolds	N	nt (R)	–
15200	*A. thompsoniae* Groenew.	T	I (K, I)	–
15300	*A. thorncroftii* Pole-Evans	T	V (R, V)	Afforestation
15900	*A. vandermerwei* Reynolds	T	R (R)	–
16400	*A. vogtsii* Reynolds	T	R (R)	–
16500	*A. vossii* Reynolds	T	R (R, V)	–

A, Namibia; B, Botswana; C, Cape Province; E, endangered; I, indeterminate; K, insufficiently known; L, Lesotho; N, Natal; nt, not threatened; O, Orange Free State; R, critically rare; S, Swaziland; T, Transvaal; V, vulnerable.

TABLE 3.—Threatened species of *Haworthia*. See the heading to Table 2 for an explanation of the numbers in column 1. Taxa that lack numbers in the first column are not upheld in Arnold & De Wet (1993). With the exception of *H. koelmaniorum* (Transvaal), *H. limifolia* var. *limifolia* (Transvaal, Natal, Swaziland, Mozambique), *H. limifolia* var. *ubomboensis* (Swaziland), *H. limifolia* var. *gigantea* (Natal), and *H. mcmurtryi* (Transvaal), all the species occur in the Cape Province. See the footnote to Table 2 for an explanation of the conservation status symbols, and the heading to Table 2 for the sources of the past conservation status given in brackets in column 3.

No.	Taxon	Conservation status	Reason for decline
460	*H. archeri* W.F. Barker ex M.B. Bayer var. *archeri*	V	Collectors; agriculture (wheat)
–	*H. archeri* W.F. Barker ex M.B. Bayer var. *dimorpha* M.B. Bayer	E	Collectors; agriculture (wheat)
2200	*H. blackburniae* W.F. Barker	R (R)	Localized, collectors
2450	*H. bruynsii* M.B. Bayer	V	Collectors
3000	*H. comptoniana* G.G. Sm.	E	Collectors; agriculture
4600	*H. emelyae* Poelln. var. *emelyae*	V	Collectors
–	*H. emelyae* var. *multifolia* M.B. Bayer	E	Collectors
4700	*H. fasciata* (Willd.) Haw. fa. *fasciata*	R	Urbanization
4900	*H. floribunda* Poelln.	V	Agriculture (wheat, barley)
5800	*H. graminifolia* G.G. Sm.	R	Collectors
6400	*H. heidelbergensis* G.G. Sm.	V	Agriculture (wheat)
8050	*H. kingiana* Poelln.	E	Agriculture; collectors; road construction
8100	*H. koelmaniorum* Oberm. & D.S. Hardy	V (R, V)	Collectors; medicinal
8600	*H. limifolia* Marloth var. *limifolia*	V	Medicinal
8650	*H. limifolia* Marloth var. *ubomboensis* (I. Verd.) G.G. Sm.	I	Medicinal
–	*H. limifolia* Marloth var. *gigantea* M.B. Bayer	V	Medicinal
8800	*H. lockwoodii* Archibald	V	Collectors
–	*H. magnifica* Poelln. var. *atrofusca* (G.G. Sm.) M.B. Bayer	E	Agriculture
–	*H. magnifica* Poelln. var. *major* (G.G. Sm.) M.B. Bayer	E	Agriculture
–	*H. magnifica* Poelln. var. *paradoxa* (G.G. Sm.) M.B. Bayer	E	Agriculture; alien plants
9600	*H. marginata* (Lam.) Stearn	E (I)	Collectors; agriculture; development
9800	*H. maughanii* Poelln.	V (I)	Collectors; ostrich farming
–	*H. mcmurtryi* C.L. Scott	I	Localized; collectors; medicinal?
–	*H. mirabilis* (Haw.) Haw. subsp. *badia* (Poelln.) M.B. Bayer	E	Agriculture; development; quarrying
–	*H. mirabilis* (Haw.) Haw. subsp. *mundula* (G.G. Sm.) M.B. Bayer	E	Agriculture
10550	*H. mutica* Haw.	V	Collectors; agriculture
–	*H. nortieri* G.G. Sm. var. *globosiflora* (G.G. Sm.) M.B. Bayer	V	Collectors; overgrazing
11600	*H. parksiana* Poelln.	E	Collectors; coastal development
11950	*H. pehlemanniae* C.L. Scott	E	Collectors
12800	*H. poellnitziana* Uitewaal	E	Agriculture (wheat)
1300	*H. pubescens* M.B. Bayer	V	Localized; collectors
13200	*H. pygmaea* Poelln.	E	Agriculture; coastal development
–	*H. retusa* (L.) Duval var. *dekenahii* (G.G. Sm.) M.B. Bayer	E	Agriculture
15200	*H. serrata* M.B. Bayer	E	Agriculture (wheat); collectors
15700	*H. sordida* Haw.	V	Collectors; overgrazing
15800	*H. springbokvlakensis* C.L. Scott	V (I)	Collectors
–	*H. starkiana* Poelln. var. *lateganiae* (Poelln.) M.B. Bayer	E	Collectors
17200	*H. truncata* Schönland	V (I)	Collectors
18400	*H. wittebergensis* W.F. Barker	R	Collectors; overgrazing
18500	*H. woolleyi* Poelln.	V	Collectors; overgrazing

TABLE 4.—Threatened species of *Astroloba, Gasteria* and *Poellnitzia*. See the heading to Table 2 for an explanation of the numbers in column 1. Taxa that lack numbers are not upheld in Arnold & De Wet (1993). With the exception of *G. batesiana* (Transvaal, Swaziland, Natal) and *G. croucheri* (Natal, Cape Province), all the species occur in the Cape Province. See the footnote to Table 2 for an explanation of the conservation status symbols, and the heading to Table 2 for the sources of the past conservation status given in brackets in column 3.

No.	Taxa	Conservation status	Reason for decline
–	*Astroloba herrei* Uitewaal	R	Agriculture; collectors
500	*Gasteria batesiana* G.D. Rowley	K	Dam construction; mining
550	*G. baylissiana* Rauh	E	Very localized
–	*G. bicolor* Haw. var. *lilliputana* (Poelln.) Van Jaarsv.	R (K)	Localized; agriculture
1500	*G. croucheri* (Hook. f.) Baker	V	Medicinal
1850	*G. ellaphieae* Van Jaarsv.	R	Very localized
–	*G. glomerata* Van Jaarsv.	R	Very localized
–	*G. nitida* (Salm-Dyck) Haw. var. *armstrongii* (Schönland) Van Jaarsv.	K (K)	Coastal development
5550	*G. rawlinsonii* Oberm.	R	Very localized
7050	*G. vlokii* Van Jaarsv.	R	Very localized
–	*Poellnitzia rubriflora* (L. Bolus) Uitewaal	R (I)	Very localized

subgenera *Hexangulares* and *Robustipedunculares*. The extensive ethnobotanical use of *H. limifolia* Marloth in Natal, Transvaal and Swaziland is an additional factor causing an alarming decline in the numbers of the species in habitat (Hardy & Fabian 1992; Hutchings 1989; R. Scott-Shaw pers. comm.).

The rarity of most species of *Gasteria* can be attributed to the fact that they have very narrow distribution ranges, especially the species of the eastern Cape Subtropical Thicket (Table 4). The eastern Cape has a long history of aridity and climatic instability which, coupled to the high terrain diversity, provides the scenario for present-day speciation (Cowling 1983), and hence many of these taxa are probably neoendemics. This is further emphasized by the fact that many of these taxa have only recently been described. The species of *Astroloba* have

TABLE 5.—Numbers of threatened alooid taxa in conservation status categories. See the footnote to Table 2 for an explanation of the conservation status symbols.

Genus	Conservation status category					Total no. threatened	Nt/Ne	% threatened
	E	V	R	I	K			
Aloe L.	5	11	25	2	6	49	128	28
Astroloba Uitewaal	–	–	1	–	–	1	4	20
Chortolirion A. Berger	–	–	–	–	–	0	1	0
Gasteria Duval	1	1	5	–	2	9	13	41
Haworthia Duval	17	17	4	2	–	40	75	35
Poellnitzia Uitewaal	–	–	1	–	–	1	0	100
TOTAL	23	29	36	4	8	100	221	31

Nt/Ne, not threatened/not evaluated.

largely escaped the collecting activities of succulent plant enthusiasts, and the genus has never achieved the same level of popularity as the other alooid genera (Table 4).

At least at present, the predominantly grassland taxon, *Chortolirion angolense* (Baker) A. Berger, can be included in the 'Not threatened' conservation category. In pristine and well managed pastures, grazing pressure is minimal since an abundance of associated palatable grass species will be utilized preferentially. However, where possible, populations should be monitored for decline or expansion, especially since *Chortolirion* occurs in some of the most densely populated areas of South Africa (Pretoria-Witwatersrand-Vereeniging region) (Smith 1994b). The other monotypic alooid genus, *Poellnitzia*, is limited to rocky hillocks in the Worcester-Robertson Karoo portion of the Succulent Karoo Biome of southern Africa. Although neither urbanization nor agriculture currently poses a problem to the survival of this species, its restricted geographical distribution range on a world basis warrants its classification as 'Critically Rare' (Table 4; Smith 1994b).

It is interesting to note that no taxa were placed in the 'Out of Danger' category (Tables 2–4). This implies that there have been no effective conservation measures to safeguard any taxon and the factors threatening the taxa are still in operation. It could be argued that the extent of the threats has possibly declined to a certain extent, as nine *Aloe* taxa had their conservation status downgraded (Table 2). However, seven of these were reclassified as 'not threatened', largely as a result of nomenclatural changes (three cases) or the discovery of new populations.

DISCUSSION

With the establishment of the Union of South Africa in 1910, the responsibility for wildlife protection was accepted by the four provinces (Section 85, Paragraph 10 of the South Africa Act, 1909), and it has remained virtually unchanged since then (Glavovic 1993). Species of Aloaceae occur in all four provinces of South Africa. In the Cape Province, the protection of these taxa is governed by Ordinance 19 of 1974 (Schedule 3: Endangered Flora and Schedule 4: Protected Flora). *Aloe pillansii* L. Guthrie, *A. buhrii* Lavranos and *A. erinacea* D.S. Hardy are listed as endangered while all the other species of *Aloe* (except *A. ferox* Mill.) and all the species of the genus *Haworthia* and *Gasteria beckeri* Schönland (a synonym of *G. nitida* (Salm-Dyck) Haw. var. *nitida*) are treated as protected flora (for a complete list see Le Roux & Schelpe 1981). The Ordinance on Nature Conservation of the Orange Free State (Ordinance 8 of 1969, Schedule 6; Protected Plants, Section 30) makes provision for the protection of all 11 species of *Aloe* (including *A. ferox*) that occur in the province (Anon. 1980). All the species of *Aloe* indigenous to the Transvaal are also protected (Nature Conservation Ordinance 12 of 1983, Schedule 11, Protected Plants, Section 86(1)(a) and Schedule 12, Specially Protected Plants, Section 86(1)(b), cf. Onderstall 1984), with the exception of *A. aculeata* Pole-Evans, *A. ammophila* Reynolds, *A. arborescens* Mill., *A. barbertoniae* Pole-Evans (a synonym of *A. greatheadii* Schönland var. *davyana* (Schönland) D.S. Hardy & Glen), *A. castanea* Schönland, *A. davyana* Schönland

(a synonym of *A. greatheadii* Schönland var. *davyana* (Schönland) D.S. Hardy & Glen), *A. globuligemma* Pole-Evans, *A. grandidentata* Salm-Dyck, *A. lutescens* Groenew., *A. marlothii* A. Berger, *A. mutans* Reynolds (a synonym of *A. greatheadii* Schönland var. *davyana* (Schönland) D.S. Hardy & Glen), *A. parvibracteata* Schönland, *A. transvaalensis* Kuntze and *A. wickensii* Pole-Evans (a synonym of *A. cryptopoda* Baker), and all species not occurring naturally in the Transvaal. In addition, all species of *Gasteria* and *Haworthia* are regarded as protected plants in the Transvaal, but none of them are listed as Specially Protected Plants. Chapter XI (Protected Indigenous Plants) of the Nature Conservation Ordinance (No. 15 of 1974) of Natal decrees as protected all the plants indigenous to the Republic of South Africa and Namibia, except those listed in Schedules 10 and 12 (Anon. no date). All Liliaceae (including aloes, gasterias and haworthias) are included in Schedule 12 (Specially Protected Indigenous Plants).

There are no specific protection laws for plants in Botswana (Hargreaves 1992), although plants are protected in the national parks, game reserves and forest reserves by the National Parks Act of 1968 (amended in 1976 and 1979) and the Forest Act of 1976 (WCMC 1991). None of these conservation areas, however, are in the east of the country where most of the succulent species, including the Aloaceae, occur. There is an urgent need for plant conservation legislation in Botswana.

The national flower of Lesotho is the unique and highly endangered *Aloe polyphylla* Schönland ex Pillans. This species was first given formal protection in 1938 by a Proclamation issued by the Resident Commissioner of Basutoland, which prohibited its removal, export, sale or destruction (Talukdar 1983). This Proclamation was replaced in 1967 by the Historical Monuments, Relics, Fauna and Flora Act (Act No. 41) which set out regulations protecting the flora of Lesotho. This Act also made provision for the formation of the Protection and Preservation Commission (PPC) whose responsibility it is to enforce the Act. On the advice of the PPC the government issued a Legal Notice (No. 36 of 1969) in which the Protected Flora of Act 41 was defined. The first item in the schedule of protected flora provides for the protection of all *Aloe* species including *A. polyphylla* in particular, and also its seeds and flowers (Talukdar 1983). The PPC followed this up with a Public Notice in 1970 which prohibited the removal and/or export of *A. polyphylla*. Despite all this legislation, protection has very rarely been enforced and the populations of *A. polyphylla* have continued to decline (Donnay & Meyer 1991). In 1970 this species was listed as Rare (Mellville 1970), in 1978 as Vulnerable (Lucas & Synge 1978) and in this survey as Endangered (Table 2). Although not likely to become extinct within the next five years, an integrated conservation action plan is required for *A. polyphylla*. In addition to traditional conservation measures, this plan must include the involvement of local village chiefs and headmen and an active public information and education campaign.

In Swaziland, all aloes are considered to be ‘protected native flora’ under the Flora Protection Act of 1952 (Braun & Prendergast 1992; WCMC 1991). As with

Lesotho, there are doubts as to how well enforced this legislation is, especially in view of the fact that Swaziland is not a signatory to CITES (see below) (Braun & Prendergast 1992).

The Nature Conservation Ordinance (Act No. 4 of 1975 as amended in 1987, Schedule 9) of Namibia, declares all species of *Aloe*, *Chortolirion bergerianum* Dinter (a synonym of *Chortolirion angolense* (Baker) A. Berger), *Gasteria ernesti-ruschii* Dinter & Poelln. (a synonym of *G. pillansii* Kensit var. *ernesti-ruschii* (Dinter & Poelln.) Van Jaarsv.), *G. pillansii* Kensit and *Haworthia tessellata* Haw. var. *engleri* (Dinter) Poelln. (a synonym of *H. venosa* (Lam.) Haw. subsp. *tessellata* (Haw.) M.B. Bayer) to be protected plants. This Ordinance and Schedule are currently being revised by the conservation authorities to enable stricter legislation for the protection of threatened species in Namibia (M. Strohbach pers. comm.).

International legal conservation measures have been developed with the introduction of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Bräutigam 1991; De Klemm 1990). The Convention came into force in 1975 and has now been ratified by over 100 countries, including Botswana, Namibia and South Africa (Swaziland is not a signatory and Lesotho, although a signatory, has not as yet ratified the Convention). The species of Aloaceae covered by the provisions of CITES are listed in two Appendices to the Convention. *Aloe albida* (Stapf) Reynolds, *A. pillansii*, *A. polyphylla*, *A. thorncroftii* Pole-Evans and *A. vossii* Reynolds are listed in Appendix I, which includes species believed to be threatened with extinction in the wild and which are or may be affected by trade. Commercial trade in wild-collected plants of these species is prohibited, but export of specimens is allowed provided that the necessary import and export permits (in that order) are obtained from the relevant authorities. Artificially propagated plants of Appendix I species are treated as Appendix II species. Appendix II is for species which although not necessarily threatened with extinction, may become so unless trade in such species is strictly regulated. International trade is controlled by the issuing of export permits for wild-collected plants and phytosanitary certificates for artificially propagated specimens. All species of *Aloe* (# 6) not included in Appendix I are listed in Appendix II; '# 6' indicates all parts and derivatives, except: (a) seeds and pollen; (b) tissue cultures and flasked seedling cultures; and (c) separate leaves and parts and derivatives thereof of naturalized or artificially propagated plants of the species *Aloe vera* L. (CITES 1992). Apart from *Aloe*, no other members of the Aloaceae are listed on the CITES Appendices.

In 1991 the CITES Secretariat commissioned the World Conservation Monitoring Centre to conduct a survey of trade in CITES Appendix II species for the period 1983 to 1989. The results of the analysis of trade data for *Aloe* species were recently published (Oldfield 1993a). An examination of the results [cf. Tables 5 and 6 in Oldfield (1993a)] shows that 30 southern African species of *Aloe* were traded, 12 of which are considered to be threatened according to this survey. Although many of these threatened species were artificially propagated, specimens of at least five species were wild-collected. In general, the CITES

statistics do not appear to be cause for concern, although there is significant international trade in aloe plants reported only at the generic level, which may conceal trade in rare plants (Oldfield 1993a). It is also probable that a large amount of trade is not reported or detected. The survey on trade in aloes also revealed that there was large-scale trade in parts and derivatives from wild populations of *Aloe ferox* in South Africa (Oldfield 1993a). The leaves of *A. ferox* are harvested to extract the mucilaginous gel and the bitter exudate known as 'bitter aloes', which are used by the pharmaceutical and cosmetic industries (Newton 1993). Oldfield (1993a) concluded that trade does not currently appear to have a detrimental impact on this widespread southern African species. However, recent increases reported in South African exports of aloe products, an industry worth about R2,5 million in 1992, prompted the South African branch of TRAFFIC (Trade Records Analysis of Fauna and Flora in Commerce) to conduct a survey of, amongst others, the conservation implications of the trade (Newton 1993). The publication of the report is now awaited and should provide insight into the wisdom of excluding *A. ferox* from conservation legislation in the Cape Province, its major centre of distribution.

Despite all of the above-mentioned commendable legislative attempts to regulate the controlled collecting and exporting of Aloaceae, there is still an urgent need to educate the public at large with regard to the importance of conservation measures. Conservation legislation alone will not solve problems related to the overexploitation of our natural resources. During the *Aloe* craze of the 1960s and 1970s which was sparked off by the publication of a series of scientific and popular treatises on the genus (Bornman & Hardy 1971; Jankowitz 1975; Jeppe 1969; Reynolds 1950, 1966), specialist collectors established a demand for rare and difficult-to-grow species, a demand which is still evident in Europe today (Jenkins 1992). Although this craze has diminished to a certain extent within South Africa, it could always recur and we need to watch out for such resurgences of interest. Due to the increasing ease of field-collecting, particularly new roads and vehicles which allow collectors access to remote and inhospitable areas (Castle 1990; Hunt 1991), the population sizes of species with naturally limited distributions could well diminish further in the foreseeable future. A distinction also needs to be made between individuals as private collectors or individuals who do so for commercial gain. The latter can be regulated as they need to bulk transport, store and distribute their plants. Unless definite attempts are made to involve amateur botanists and the informed public (e.g. members of the Succulent Society of South Africa) in educational programmes on the sustainable utilization of our plants, costly legal proceedings instituted against transgressors will remain the only alternative (Anon. 1992, 1993). Perhaps the Conservation Code of Conduct adopted by the International Organization for Succulent Plant Study (IOS) could serve as a role model of the approach to follow (Oldfield 1990).

In short, we as botanists need to be active in changing the perception that plant conservation is an elitist activity reserved for First World countries. Our biotic resources should not be perceived as finite, as recently shown by an ongoing study to revise the *Red data book* for Karoo plants (Hilton-Taylor 1993). Prelimi-

nary results of the investigation have shown that the number of threatened succulents in the Succulent Karoo Biome has increased from 183 to 350 within a period of approximately eight years. Although the increase can be attributed largely to more comprehensive and accurate information derived from the Red Data investigation itself, increased agricultural, mining and construction activities in the region also play an important part.

At the Inter-Congress meeting of the IOS which was held from 24–31 March 1993 in Qawra, Malta, the Cactus and Succulent Specialist Group of the Species Survival Commission (SSC) of the IUCN worked out details for the writing of a worldwide Action Plan for the conservation of succulents (Oldfield 1993b). The Plan for the Aloaceae reviews the taxonomic and conservation status of the family and has been prepared by E.J. van Jaarsveld and G.F. Smith. Apart from being descriptive, the Plan is intended to be action-oriented in that it should be used to save species. Some of the projects which should receive attention in the foreseeable future include: determining which threatened Aloaceae are represented in gene and seed banks, botanical gardens, nature reserves and private collections; the establishment of reserves, especially in regions of high Aloaceae species diversity, such as the eastern Cape (Smith & Marx 1990); the education of land owners with regard to threatened species that occur on their property; the promotion of pharmacognostical research on the Aloaceae; and the *ex situ* conservation of threatened species through their introduction to suitable botanical gardens. An essential issue that needs to be addressed is the discrepancies in national and provincial legislation concerning alooid conservation (Smith 1994c). For example, Zimbabwe, although falling outside the study area, is the only southern African country where all the natural *Aloe* hybrids existing in the wild are Specially Protected Plants, in addition to the 30 indigenous species and two varieties (Zimbabwean Parks and Wildlife Act of 1975, cf. Kimberley 1975, 1980, 1992). Further, all the southern African species of *Aloe* are protected in Natal, whereas legislation in the Transvaal explicitly excludes all the extraprovincial species from protection by the relevant Ordinance. Perhaps most importantly, we need to establish a conservation ethic in which the Aloaceae, along with the rest of our flora, is viewed by the entire community as an important and irreplaceable resource.

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Rehabilitation and development of The Limbe Botanic Garden, Cameroon

N. NDAM

The Limbe Botanic Garden, P.O. Box 437, Limbe, Cameroon.

ABSTRACT

The Limbe (Victoria) Botanic Garden was founded in 1892 by the German Colonial Administration. The purpose was to introduce useful plants for later cultivation in Cameroon and other German colonies. Training in agricultural, botanical and chemical research were some of the key roles. The Garden quickly achieved a high international reputation. From the onset of the First World War, it entered a period of decline. A revival took place in the early 1920s under Kew-trained management. The functions of the Garden included agricultural investigations, forestry and horticultural development. By the early 1930s the Garden was again in decline. This cyclical change of circumstances has continued until the late 1980s.

Since 1988, the Cameroon Government and the British Overseas Development Administration have collaborated to develop the Garden as a regionally important public resource for cultural and recreational activities, a centre for environmental awareness programmes, and a base from which scientific research in the nearby forests can be undertaken.

This paper summarizes the rehabilitation programme, its objectives and achievements.

INTRODUCTION

The Limbe Botanic Garden, Cameroon (previously called The Victoria Botanic Garden), is at the foot of Mount Cameroon, the highest mountain in Central and West Africa. The garden is situated in the town of Limbe (65 000 inhabitants) and is only an hour's drive from Douala International Airport. From the Garden, the nearby rainforest can be reached in as little as another 30 minutes (Figure 1).

The Garden has a pleasantly varied landscape rising from the Atlantic coast. There are two hills of 90 m—one in the eastern, the other in the western half of the Garden. From these hills visitors can view the Atlantic, the islands in Ambas Bay, the island of Bioko (Equatorial Guinea), the town of Limbe and the clear waters of the River Limbe running throughout the length of the Garden. These natural features of the Garden are important attractions for both Cameroonian and international visitors.

BRIEF HISTORY

Limbe Botanic Garden was established by the Germans in 1892 and originally occupied an area of 120 ha. It served as a testing and acclimatization centre for the introduction of exotic plant species. These plants formed the basis for the establishment of cash crop plantations in Cameroon and other German colonies. Many plants introduced to the Garden such as coffee, cocoa, tea and rubber contributed to the bustling economy of Cameroon. Some useful fruit trees were also introduced and today constitute a major source of commercially available fruits in Cameroon. The excellent performance of these tropical crops and fruits helped the Garden gain a high international reputation.

At the onset of the First World War, the Botanic Garden entered a brief period of decline, which was reversed in the early 1920s under British management, supported by the Royal Botanic Garden, Kew. During this period the functions of the Garden included acting as a training centre in addition to undertaking agricultural development and research on forestry and horticulture. The collections achieved international standards. However, a decade later they started to decline. Despite the efforts of many people, this cyclical change of circumstances continued until after Independence of that part of Cameroon in 1961.

Following Independence, the Botanic Garden and its facilities faced major adversity. Owing to the neglect of the Garden, some structures were misappropriated. For instance, the building originally serving as the Garden's laboratory and library, became a hospital and today it is one of the major hotels in Limbe. The expansion of the town reduced the size of the Garden from 120 to 48 ha. The misuse of the Botanic Garden's assets continued as private houses were built along the coast and the main entrance was used as a thoroughfare for private premises. Road materials were quarried from the Garden on a very large scale. The fences were broken and part of the Garden was used as a municipal rubbish tip. Bathing and the washing of laundry became a common feature in the River Limbe which flows through the Garden. Trees and other plants were arbitrarily cut down and private farms established. Maintenance was reduced to 7 ha, the rest of the Garden reverting to bush which provided useful escape routes for the thieves that preyed on visitors. All these problems made visitors feel unwelcome in the Garden.

Eventually, the Garden's decline became a cause for concern for those who remembered its better days. From 1982 they started to express their concern over its progressive deterioration (Womersley 1982). The Government was therefore encouraged to increase its funding and to investigate ways to facilitate its improvement. The maintenance of the Garden started anew, but the task was too great for local support, and efforts were made to secure assistance. In 1986, two British teams visited Limbe. This contact led to the recommendation that the rehabilitation of the Botanic Garden should form part of a programme to establish reserves for genetic resource conservation in the nearby rainforest on the slopes of Mount Cameroon (Hepper *et al.* 1986; Hepper & Bovey 1987).

RECENT DEVELOPMENTS

The current phase of Garden renovation, the 'Limbe Botanic Garden and Rainforest Genetic Conservation Project', started in June 1988 as a programme bilaterally funded by the British and Cameroonian governments. The project started with two British technical advisers (a forester/conservationist and a horticulturist) and their Cameroonian counterparts.

The objectives of the project were to renovate the Botanic Garden and to survey the nearby forests to identify areas of conservation priority and to develop a strategy for their long-term, sustainable use.

The renovation of the Garden commenced with clearing overgrown areas, moving tonnes of lava and thoroughly digging out elephant grass and tree stumps. Gradually the vegetation was tamed and a maintenance routine established. The filling of holes and levelling of the ground began. This enabled the tractor and lawnmower to cover greater areas and improved the standard of maintenance. The area of the Garden under regular maintenance progressively increased from 7 to 48 ha. Mechanical and manual techniques were critically analysed to improve efficiency and performance.

Staff began to receive training and there was a gradual improvement in standards. Throughout the rains all Garden labourers (11 initially and 30 now) are employed to repeatedly cut the overgrown areas of grass. In the dry season the same people are available for a wide range of developmental work.

Significant repairs on the old German sea wall were undertaken to stop erosion in the Garden. The fence was repaired or replaced, increasing the security of the Garden. Public access to the major parts of the Garden was improved. The Jungle Village, a natural amphitheatre with seating for about 3 000 people, is situated in the heart of the Garden. It was renovated and now provides a spectacular venue for a range of public events. Other dilapidated structures have also been renovated for official use. The working facilities of the nursery have been improved and the rehabilitation phase is almost completed. The first phase is being followed by a strategy developed to fulfil the selected roles of the Garden: conservation, education, tourism and science.

CONSERVATION AND SCIENCE

The Botanic Garden aims to support the conservation of forests in the vicinity for sustainable use by the local population. It also aims to encourage scientific studies in order to understand the natural resources and promote their uses for the benefit of mankind.

The Garden has been developed to serve as a base from which scientific studies in the vicinity can be undertaken (Bovey 1993). It is a potential repository for increasing information on the regional forests (material, literature and local staff

knowledge). From the Garden, specialists can quickly travel to collect specimens and field data, and return to the Garden to conduct experiments and collate their notes. As a research base, the Garden offers a library and a fast-developing, air-conditioned, regional herbarium.

The management has renovated historical buildings within the Garden to provide air-conditioned, self-catering accommodation for visiting scientists, at a nominal rate, and staff can sometimes offer transport to the forest.

The nearby forest, on the slopes of Mount Cameroon, is unique in West and Central Africa in having an unbroken vegetation gradient from rainforest, almost at sea-level, through to alpine flora at 4 095 m. With over 45 endemic plant species, two endemic species of birds, four endangered primates and the forest elephant, the site is of international conservation priority (Gartlan 1989). The Garden has the potential to act as a centre from which information on the uniqueness of Cameroon's fauna and flora could be disseminated to the populace. If successful in influencing people to support the sustainable utilization and sensible conservation of the region's natural resources, there may be fewer pressures placed upon the conserved areas of Mount Cameroon, facilitating more effective management. In this capacity the Garden has considerable potential to influence the long-term success of national and regional conservation policies (Ndam 1992).

The Garden planting scheme offers the possibility of establishing living collections complementary to those found in the nearby forests. With the participation of national and international scientists and the use of local knowledge, the inventory of the forest around Mount Cameroon has begun. This work, along with other activities in the field, has improved the knowledge of habitat needs of some useful plant species. The resultant knowledge together with information on the uses of particular plant species will be valuable for the local people and for medicinal research.

EDUCATION AND RECREATION

One of the primary objectives of the Limbe Botanic Garden is the development of an environmental education programme. It is hoped that this objective will be achieved through formal and informal education at both individual and group levels. The location of the Garden is ideal, with the potential for developing a wide range of habitats naturally found in Cameroon. Themes that are being developed to represent local ecosystems include lowland rainforests as well as maritime, wetland and riverside forests. African and Cameroonian plant species used for medicine, tropical fruits from throughout the world and other useful species constitute some of the other themes gradually being established. It is hoped that when developed, collections of various selected themes will illustrate the importance of plant products to all mankind. The Garden is therefore being developed to attract and educate its visitors.

An important aspect of the work of the Garden is to promote the beauty of native plants that are currently unappreciated by the populace. Plants are arranged so as to form attractive displays. Local people already take pride in bringing their friends and family to the Garden. School children are increasingly utilizing the Garden as a quiet place to study or relax. If encouraged to respect nature, they may form a new generation who will protect and manage our irreplaceable heritage. Educating the younger generation is a sure path towards a better protected future, and for this reason the Garden opens its gates to people of all ages. The public is encouraged to use the Garden for recreational activities such as picnicking, traditional dancing and wrestling competitions.

Information panels are displayed for public viewing and static displays are changed every few months. Meetings, daytime and evening lectures, guided tours, videos and slide shows all provide regular entertainment and information for the public. The Garden provides ideal conditions for teacher workshops on environmental education. It is hoped that as a result, school curricula could be influenced to take into account environmental concerns.

The Garden also provides education on the sustainable use of natural resources. The staff have held courses to introduce the population to appropriate bee-keeping techniques. These techniques allow honey to be produced without damaging the forest, and the money generated can provide alternative sources of income for forest users. A model chop-farm has been developed in the Garden to demonstrate improved agricultural practices to visiting farmers.

CONCLUSION

The Limbe Botanic Garden, its plantings and facilities are now revitalized (Besong *et al.* 1993). It offers a comfortable research base for scientists. New plantings have started to develop, forming the thematic collections selected for the Garden. People of all ages and levels of Cameroonian society increasingly come and appreciate the Garden and so gain an understanding of the vast resources their region has to offer. The Garden currently enjoys sound public support, which needs to be maintained. One way to achieve this is to regularly provide new information to the public in a manner which facilitates easy understanding. This requires specialized knowledge and skills. The rehabilitation of the Garden demonstrates the potential effectiveness of international collaboration in conservation. The management of the Limbe Botanic Garden is particularly interested in contributing to the promotion of African biological diversity and it is hoped that the South African meeting will be a good beginning.

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The Convention on Biological Diversity: challenges and opportunities

S.C. NJUGUNA
IUCN Eastern Africa, Biodiversity Conservation Programme,
P.O. Box 68200, Nairobi, Kenya.

ABSTRACT

The biological diversity, or biodiversity, of a country is the totality of the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur. This includes life within terrestrial as well as marine and freshwater ecosystems. A record number of over 160 governments or over 90% of the members of United Nations signed the Convention on Biological Diversity within a year of its proclamation. The treaty is a landmark convention, pursuing for the first time a comprehensive rather than a sectoral approach to the conservation of biodiversity and the sustainable use of its components.

The Convention on Biological Diversity focuses initially on the gathering of information through national surveys and inventories, and then moves to address the benefits arising from the sustainable use of biodiversity. The gathering of information is undertaken by Biodiversity Country Studies which detail what is currently known about the status, threats, costs and benefits of biodiversity conservation in each country. The Biodiversity Country Studies, therefore, constitute the first systematic step for countries to undertake in order to establish the baseline information on their biological diversity. These studies would, ultimately, form the basis for the preparation of National Biodiversity Strategies and related Action Plans.

INTRODUCTION

The Convention on Biological Diversity, whose text was adopted on 22 May 1992 in Nairobi and a few days later signed by 156 governments during the Earth Summit in Rio de Janeiro, is the culmination of a process that has its roots in the evolution of interest in environmental issues in the 1940s. The work of the World Conservation Union (IUCN) gave concerns about the loss of biodiversity an institutional backing. The United Nations Conference on the Human Environment held in Stockholm in 1972 gave issues of biological diversity political and legal legitimacy. It is, however, the work of the World Commission on Environment and Development, contained in the report, Our Common Future (WCED 1987), which prompted the first significant and systematic steps to bring to the attention of the international community the urgency of identifying and instituting long-term measures to conserve biological diversity.

UNEP, working on earlier drafts from IUCN, took the global concerns regarding the management of biological diversity further, and in effect, established the machinery which led to the formulation and adoption of the Convention on Biological Diversity. The Convention came into force on 30 December 1993, the ninetieth day after the date of deposit of the thirtieth instrument of ratification, acceptance, approval or accession.

The Convention on Biological Diversity defines 'biological diversity' in Article 2 as 'the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes the diversity within species, between species and of ecosystems.' The objectives of the Convention are outlined in its Article 1 as 'the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of utilization of genetic resources.'

These objectives will be achieved with the aid of appropriate funding and will include appropriate access to genetic resources and appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies.

Overuse and inappropriate exploitation of biological diversity must be prevented and more diversified, equitable, and sustainable approaches to the use of biological resources discovered, promoted and implemented. The process of understanding and promoting wise management of biological diversity can be enhanced through the development of proactive strategies to save, study and appropriately use biological diversity. The Convention on Biological Diversity calls for the Contracting Parties to develop national strategies, plans and programmes for the conservation and sustainable use of biological diversity (Article 6, UNEP 1992a).

NATIONAL BIODIVERSITY STRATEGIES

A National Biodiversity Strategy is a planning instrument which seeks to attain the protection, understanding and sustainable use of a nation's biological diversity (UNEP 1992b). Protecting biodiversity requires urgent action to slow or halt unsustainable paths that lead to the loss of biodiversity. Understanding biodiversity entails activities including inventory and survey of biodiversity in the wild; biological and ecological research to increase our knowledge of the behaviour and function of species and ecosystems; and the development of data and information on species, genes and ecosystems. It requires both modern science and traditional knowledge. Using biodiversity sustainably and equitably means husbanding biological resources so that they can last indefinitely, making sure that biodiversity is used to improve the human condition, and seeing that these resources are shared equitably (WRI, IUCN & UNEP 1992).

The process of planning for the protection, understanding and sustainable use of biodiversity includes the preparation of strategies which are general policy instruments, and action plans which are specific frameworks for implementation.

A National Biodiversity Strategy is prepared by mobilizing a participatory process that involves governments and other interested parties to assess a nation's biological assets, factors affecting them, and to formulate, implement and evaluate the actions required to derive the greatest benefit from the assets on a long-term basis. An Action Plan, on the other hand, is a framework for detailing a programme of activities and instruments together with associated responsibilities, expected results, budgets and institutional and personnel requirements, with specified targets and timetables. The goal of biodiversity conservation will, ultimately, best be achieved by integrating consideration of biodiversity into a single national plan for sustainable development. As an interim measure, however, most countries will need to develop a National Biodiversity Strategy document to focus attention and develop a consensus. National Biodiversity Strategies should be prepared as part of, or in follow-up to other ongoing environmental planning processes such as environmental profiles, National Conservation Strategies (NCSs) and National Environmental Action Plans (NEAPs). In the preparation of the biodiversity strategies, existing environmental planning frameworks and instruments such as *Agenda 21* and *Caring for the earth* should be used wherever possible.

The National Biodiversity Strategy and its associated Action Plans serve to articulate the needs of the nation, some of which may require various forms of international cooperation. These documents provide both the framework and the details by means of which nations can negotiate identified forms of cooperation in terms of funding, technology, science, education and training, and co-management under international agreements on species and ecosystems of common interest. Capacity building is expected to be the force that nurtures the entire process. The planning process itself is recognized as a training exercise for capacity building.

Biodiversity will be conserved and used wisely only to the extent that all resident and dependent constituencies and communities are involved fully in the planning, implementation and evaluation processes.

The term National Biodiversity Strategy implies a planning process that is applicable on a national scale. The strategic planning process, however, is one that can be applied on a variety of scales. It can be used on the scale of multinational regions, along animal migration routes or within ecological regions. It can also be used in subnational contexts to cover ecological regions, cultural or ethnic areas, states or provinces. It can be relatively simple, embracing a small area or a single sector, or it can deal with large complex areas and multiple sectors. It is important at the outset to establish the structures needed for strategy development, to define a clear, well thought out plan for gaining government adoption of the strategy, and to prepare for the launching of the strategy into the public arena.

BIODIVERSITY COUNTRY STUDIES

The conservation element of the Convention on Biological Diversity recognizes the importance of Biodiversity Country Studies in the preparation of the National Biodiversity Strategies and Action Plans. It focuses initially on the gathering of information through national surveys and inventories. This information gathering is undertaken using the UNEP methodology of reporting (UNEP & WCMC 1993). The UNEP methodology of reporting has four main components:

- identification of components of biological diversity important for conservation and sustainable use;
- identification of processes and activities likely to have adverse impact on biological diversity;
- evaluation of potential economic implications of conservation and sustainable use of biological resources; and
- suggestion of priority action for conservation and sustainable use of biological diversity.

In view of the importance of the Biodiversity Country Studies in the development of National Biodiversity Strategies and Action Plans, Convention Resolution 2 of the Nairobi Final Act on international cooperation requested the UNEP Governing Council to consider providing assistance to governments, upon request, in the preparation of Biodiversity Country Studies (UNEP 1992a). The study process, therefore, not only involves the collection and analysis of data, but also quantifies the costs and benefits of biodiversity conservation and sustainable use. The need to estimate the economic benefits accruing from the sustainable use of biological resources has strategic implications.

BIODIVERSITY INFORMATION NETWORK

Article 17 of the Convention states that:

The Contracting Parties shall facilitate the exchange of information, from all publicly available sources, relevant to the conservation and sustainable use of biological diversity, taking into account the special needs of developing countries.

Such exchange of information shall include exchange of results of technical, scientific and socioeconomic research, as well as information on training and surveying programmes, specialized knowledge, indigenous and traditional knowledge, as such and in combination with technologies that are relevant to the conservation and sustainable use of biological diversity, or make use of genetic resources and do not cause significant damage to the environment.

The sustainable management of the environment and conservation of biodiversity of plants, animals and microorganisms, and all living things depends on reliable and readily accessible information. Without information on the names,

location, activity and interaction of organisms in the ecosystems, conservation strategies and remedial actions cannot succeed.

The amount of information in existence, and soon to be developed, is vast. The sources include botany, zoology, microbiology, ecology, environmental sciences and all subdisciplines of these. The information is held in books, on cards, in reports, files and databases. The databases are in different formats, on different computers and in different parts of the region. A means to connect these resources for use by scientists, administrators, policy makers, funding agencies and the public is urgently needed.

The purpose of a regional biodiversity information network is to support the Convention on Biological Diversity and *Agenda 21*. It will do this by facilitating efficient access to information relating to all aspects of biodiversity. It will underpin the study of biodiversity, as well as its monitoring, management, use, conservation and preservation. It will promote the concept of biodiversity and encourage the development of databases, thereby supporting scientific development and conservation.

EASTERN AFRICAN EXPERIENCE

Biodiversity Country Studies

With the coordination of UNEP, funding from GEF, and WCMC playing a catalytic role, Kenya and Uganda were among the ten countries including Nigeria, Indonesia, Thailand, Germany, Poland, Bahamas, Canada and Costa Rica, that completed Biodiversity Country Studies early in 1992. The process led to the establishment of National Biodiversity Units in both Kenya and Uganda. In Kenya, the National Biodiversity Unit is housed at the National Museum of Kenya, with staff from the Museum and the National Environment Secretariat forming a coordinating task force. In Uganda the National Biodiversity Unit is located in the Department of Environment Protection, with coordinating staff from the Department, Makerere University and the Department of Forestry. The studies carried out by the two countries focused on: biodiversity data, the interface between biodiversity and sustainable economic development, and the costs and benefits of specific programmes for biodiversity conservation.

Regional biodiversity database

The first workshop was held in Bwindi, Uganda, in August 1991 and the second and third in Nairobi in April and August 1992 respectively. The fourth workshop on a regional biological database was held in Kampala, Uganda, from 23 to 26 August 1993. The fifth workshop is scheduled to be held in Dar-es-Salaam in August, 1994. The workshops' participants include scientists from a wide variety of regional institutions (government and NGO) involved in biodiversity data collection and storage. Several smaller working groups have been established to investigate issues related to specific taxonomic groups, habitat classification, and

education and training. The mission of the regional database is to ensure that decision makers who may influence the maintenance of biodiversity are provided with the benefit and knowledge of all key biological information. This would be achieved by:

- creation of data standards of the greatest utility to the end users;
- development of specific products for particular target groups;
- formation of interinstitutional linkages; and
- identification and planning of education and training needs.

Regional biodiversity metadatabase

IUCN EARO (the Eastern Africa Regional Office of IUCN) and the World Conservation Monitoring Centre in collaboration with regional and international institutions are engaged in a process of establishing a regional database of biodiversity data sources (database of databases or metadatabase) through a project titled Availability of Biodiversity Information for East Africa (IUCN & WCMC 1992). This is a survey of the sources and types of information on biodiversity for Kenya, Tanzania and Uganda held by organizations both within and outside East Africa. The mission statement of the project is ‘to promote the conservation of biodiversity by improving the availability and accessibility of biodiversity data and facilitating further information gathering.’ The project commenced in September 1992 and was expected to be completed by December 1993. One of the objectives of the project is to assess the feasibility of extending it to cover all tropical Africa with the development of a metadatabase for Africa. Collaboration with the Biodiversity Foundation for Africa, based in Bulawayo, Zimbabwe, has been initiated. The project is supported by financial contributions from the European Community and the Global Environmental Facility.

Regional plant resources study

In collaboration with l’Observatoire du Sahara et du Sahel (OSS) based in Paris and with full participation of national institutions in Kenya, Uganda, Ethiopia, Somalia, Djibouti, Sudan and Egypt, IUCN EARO is conducting a study on databases, research and conservation activities pertaining to plants in eastern Africa. The expected outputs of the study include: a metadatabase describing means to access data and highlighting limitations and gaps; identification of research priorities; and an enhanced networking. The project will also explore the feasibility of establishing National Plant Data Centres in appropriate eastern African institutions. Proposals for extending the project to the North and West African regions have been prepared.

Biodiversity advisory groups

National Biodiversity Advisory Groups have been established in Kenya, Uganda and Tanzania. An Eastern African Biodiversity Advisory Group has also been formed with current representation from Kenya, Uganda and Tanzania. It is

hoped to expand the regional representation shortly to include Ethiopia and Seychelles. Ultimately, representation will cover all countries of eastern Africa.

CONCLUSION

In conclusion, there are innumerable challenges and opportunities before us. There is an urgent need for all countries to ratify the Convention and to introduce new legislation and administrative measures dealing with such issues as the conservation of biodiversity, access to biological resources, and sharing of the benefits of the utilization of biological resources and from biotechnological development. The ratification of the Convention should be linked to the mobilization of NGOs, local communities and indigenous peoples to fully participate in the implementation process.

Developing countries need to build up research and institutional capacity in the biological and information sciences, especially in molecular biology, genetics, taxonomy and population biology. Such training should also be extended to parataxonomists. The development of information networks as part of the infrastructure for research is critical to the process of technological development. Efforts should be made to strengthen this process and to improve the policy and administrative environment for transborder data flow.

There is need to work more effectively on the application of science to management. Scientists need to give more thought to the practical implications of their work at both management and policy levels. We need to talk to politicians and donors in language they can understand. For any success in the implementation of the Convention on Biological Diversity, it is important to tap the initiative and creativity of the people who are the target as well as the agents of development in Africa. Finally, the greatest challenge of all, is the cultivation of a genuine commitment for the conservation of all species of plants and animals that exist on earth.

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TRAFFIC, wildlife trade monitoring and the South African plant trade

D.J. NEWTON and A. BODASING
TRAFFIC East/Southern Africa, Private Bag X11, Parkview, 2122 South Africa.

ABSTRACT

An introduction to TRAFFIC, the world's largest wildlife trade monitoring network, is presented. TRAFFIC's 17 offices monitor wildlife trade with special emphasis on identifying species whose survival is threatened by commercial overexploitation or whose trade is in violation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Cites). Careful analysis of trade statistics, trade dynamics and the status of species enables TRAFFIC to support biological diversity by striving to ensure that the utilization of wildlife resources is sustainable and legal. The status of the plant trade in South Africa is described with specific reference to interpretations of the often-used term 'conservation by cultivation', and to the conservation value of *ex situ* propagation of exotic plant species in South Africa.

INTRODUCTION

TRAFFIC (Trade Records Analysis of Fauna and Flora in Commerce) is the world's largest wildlife trade monitoring organization—an international network of 17 national and regional offices coordinated by TRAFFIC International, located in the United Kingdom. The TRAFFIC network was established in 1976 as a nongovernment, nonprofit organization by the World Wide Fund (WWF) and the IUCN (the World Conservation Union).

The objectives of TRAFFIC are to enhance the conservation of wildlife by monitoring and reporting on trade in wildlife and wildlife derivatives and identifying areas of trade that may be detrimental to the survival of any species. TRAFFIC assists the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), government agencies and other appropriate bodies in controlling wildlife trade and in curtailing possible threats to species created by trade. To achieve its aims TRAFFIC works in close collaboration with government wildlife authorities, customs officers, law enforcement bodies, veterinary and plant health inspectors, plant and animal traders, conservation organizations, universities and others.

TRAFFIC East/Southern Africa is the first regional programme on the African continent, covering wildlife trade issues in 17 states: Angola, Botswana, Djibouti,

Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. The TRAFFIC East/Southern Africa programme is coordinated by the regional office located in Lilongwe, Malawi, and supported by national offices in Johannesburg, South Africa, and Dar-es-Salaam, Tanzania. The South African office is sponsored jointly by the Southern African Nature Foundation (SANF), the Endangered Wildlife Trust, the Wildlife Society, the Rhino and Elephant Foundation, the Mazda Wildlife Fund and Compaq Computers.

TRAFFIC in South Africa is conducting research into the role played by South Africa in the international trade in succulent plants, tropical and temperate timbers and wild birds.

INTERNATIONAL PLANT TRADE

It is common knowledge that wild plant species are disappearing at an alarming rate. According to Fitzgerald (1989), an estimated one in ten recorded species are now considered rare or endangered. The World Conservation Monitoring Centre estimates that as many as 25 000 species, or 10% of the world's flora, are currently under some degree of threat. At least 650 plant species are recorded to have become extinct in historical times. The most serious pressures come from industrial development, air and water pollution, farming and livestock grazing, and clearance of land for timber and crop production and firewood. The world market for wild plants to decorate gardens and houses, as well as trade among specialist collectors, adds to the peril of species that are both rare and difficult to propagate.

Although no reliable figures are available, the legitimate international plant trade is conservatively worth an estimated US $1 billion annually. Fitzgerald (1989) reports that in 1984 the United States alone imported over 250 million garden and house plants. Marshall (1993) reports that in 1987 the US imported an estimated 1 billion foreign bulbs and, in 1989, Americans spent US $470 million on flower bulbs alone (figures assumed to be sum of artificially propagated and wild-collected bulbs imported into the United States). The Netherlands annually import 50 million wild bulbs, primarily from Turkey. Furthermore, Marshall (1993) reports that the vast majority of plants currently collected from the wild are harvested without any management plan or monitoring system. Harvest rates are rarely based on scientific information. No statistics are available on the overall value of the illegal trade in wild plants.

To guard against loss of wild stocks, some of the more popular horticultural plants, including all orchids (members of the family Orchidaceae) and cacti (members of the family Cactaceae), several aloes (*Aloe* species) and palms (members of the family Arecaceae [Palmae]), many cycads (members of the family Cycadaceae), and a few insectivorous plants (members of the families Sarraceniaceae and Nepenthaceae), were listed under CITES in the 1970s and early 1980s (Fitzgerald 1989). The number of plant species that receive some

degree of protection under the Convention is currently estimated at 21 664 (N. McGough pers. comm.).

CITES CATEGORIES OF PROTECTION

CITES offers three categories of protection set out in three appendices, each of which stipulates a different level of regulation:

Appendix I Includes species that are thought to be endangered and for which any commercial trade would be an impediment to their survival. All South African cycads (*Encephalartos* species) and the *halfmens* (*Pachypodium namaquanum*) are examples of species listed on Appendix I. Commercial trade in wild-collected specimens and any parts of or derivatives of these species is prohibited. Noncommercial trade is permitted under special circumstances, usually limited to educational and display purposes and scientific research.

Trade in Appendix I species requires an export permit from the country of origin or a re-export certificate from the re-exporting country, as well as an import permit from the country destined to receive the shipment.

Appendix II Lists species that can withstand certain levels of exploitation but which require a monitoring and regulation system to record levels of trade to ensure that the populations remain sustainable. Wild specimens may be traded with an export permit from the country of origin or a re-export certificate from the re-exporting country. However, export permits are to be issued only if the specimens are legally acquired and if trade in the specimens is determined not to be detrimental to the survival of the species. Propagated plants may be traded with a certificate of artificial propagation. Among the South African plant species listed on Appendix II are *Euphorbia* species and most orchids.

Appendix III Lists species subject to regulation within individual countries and for which the cooperation of other countries is sought to control that trade.

THE SOUTH AFRICAN PLANT TRADE

South Africa is unique in the world because, with its relatively wealthy economy and rich biodiversity, it is both a producer and a consumer of wildlife products. It has a well-developed market infrastructure which places businessmen in a good position to act as dealers and as middlemen in the international wildlife trade.

South Africa has one of the richest floras in the world. The country's plants are used for a wide variety of purposes. They are used to landscape ordinary

homes and gardens and are collected by hobbyist and specialist collectors, e.g. species of *Aloe* and *Encephalartos*. Some species are used by pharmaceutical companies for preparing medicines and cosmetics (e.g. *Aloe ferox*, the bitter aloe) or for other industrial products. Indigenous timbers are utilized by rural communities for building materials or for carving crafts or other products (e.g. *Pterocarpus angolensis*, *kiaat*). Other plants are used as food (e.g. *Sclerocarya birrea*, the marula tree), as traditional medicines (e.g. *Warburgia salutaris*, pepper-bark tree), or as material for weaving and thatching (e.g. *Thamnochortus insignis*, *dakriet*).

Players in the plant trade

Given the great interest in South African plants locally and overseas, it is important to identify persons and institutions involved in the trade. Players in the trade include scientists, specialist plant traders, gardeners, horticulturists, landscaping companies, individual members of amateur and professional clubs and societies, government conservation agencies, nongovernment organizations and practitioners of traditional medicine and their patients. From the broad list described it is probable that a substantial proportion of the public in South Africa is involved in the plant trade, either as consumers or as participants in the service industry, thereby helping to drive it. Whether buying plants for a garden, buying ebony ornaments for decoration or using plants for medicine, the responsibility for conserving and managing plant resources rests firmly in the hands of every individual. Unfortunately, detrimental trade in wild plants often continues today due to lack of awareness on the part of consumers. Many gardeners and other users of plants are unaware of conservation concerns and do not know which species are rare, threatened, or endangered. Many do not know whether their plants are wild-collected or artificially propagated and therefore unwittingly contribute to the demise of species.

Trade statistics

According to CITES statistics, from 1976 to 1992, South Africa exported an estimated total of 50 000 plant specimens, representing approximately 220 species. These figures are for live plants only and do not include large volumes of seeds and plant extracts and derivatives. South Africa exports its fauna and flora to almost 100 countries around the world. Some of the most common destinations for South African plants are Germany, Italy, Japan and the United States of America.

The trade figures given above are small in international terms. They are also misleading because they only reflect the trade in CITES species and, in fact, represent only a relatively small part of the total trade in South African plants. Ample evidence for a larger trade in plants has been found while studying succulent plant markets in Europe and the United States. Encompassing South African genera from the plant families Aizoaceae (Mesembryanthemaceae), Aloaceae, Apocynaceae, Asclepiadaceae, Asphodelaceae, Asteraceae, Brassicaceae, Chenopodiaceae, Crassulaceae, Dioscoreaceae, Dracaenaceae,

Euphorbiaceae, Geraniaceae, Goodeniaceae, Hyacinthaceae, Lamiaceae, Liliaceae, Passifloraceae, Pedaliaceae, Piperaceae, Portulacaceae, Rubiaceae, Sterculiaceae, Vitaceae and Zygophyllaceae, the study revealed that almost 2 600 succulent plant species (including subspecies), out of a total of about 6 000 species, are currently being offered for sale in nurseries. Taking these data for succulent plant species into account, the total number of South African plant species in international trade is significantly higher than the figures derived from CITES trade statistics indicate. Without further research, it is not possible to account with certainty for the large discrepancies between declared CITES exports and the number of plant species being sold on overseas markets. However, a portion of the discrepancy may be accounted for by the following factors:

1. Nine families, namely Orchidaceae, Liliaceae, Cyatheaceae, Portulacaceae, Asclepiadaceae, Zamiaceae, Euphorbiaceae, Proteaceae and Apocynaceae, encompassing South African plant genera such as *Aloe*, *Anacampseros*, *Encephalartos*, *Euphorbia* and *Pachypodium*, are included in the CITES Appendices. Formal CITES export records are kept only for the CITES-listed species within these families but not for nonCITES-listed genera. The number of South African species that must be reported is therefore limited and does not reflect the true volume of plants in trade. Provincial Nature Conservation authorities are responsible for logging exports of all nonCITES plant species in South Africa. Compilation of these data will certainly throw more light on the true volume of South Africa's plant trade.

2. Seed has been supplied overseas to enthusiasts and nurseries by botanical institutions and commercial South African nurseries for many years. Plants derived from seed are artificially propagated, multiplied and sold, sometimes in massive volumes. For example, in 1991, plant dealers in Denmark exported an estimated 40 000 artificially propagated plants of *Ceropegia woodii*. It is possible that many South African species find their way to foreign markets as a result of such mass propagation.

3. The smuggling of wild-collected plants out of South Africa using the postal system and in the personal baggage of travellers is reported to be common, but this activity is difficult to identify and quantify. Some of the South African species found in the German study cited above are likely to include specimens that were smuggled.

The illegal plant trade

It appears that the smuggling of wild-collected indigenous plants continues unabated and is threatening the survival of certain plant species in South Africa. The magnitude of smuggling operations has not been quantified, but TRAFFIC research conducted during 1994 into three confiscated shipments of smuggled plants shows that smuggling constitutes a threat to indigenous plants such as

Othonna halli, *Pelargonium rapaceum*, *P. karooicum* and *Ornithogalum* species amongst others. Rare plants such as *Haworthia magnifica* and *H. pygmaea* currently offered for sale in nursery catalogues in Europe may also have been smuggled to these international destinations. Rare plants, with origins as far away as Southeast Asia, are also smuggled into South Africa. This was plainly demonstrated at the 1st International Paphiopedilum Symposium in July 1993 in Pretoria where TRAFFIC discovered 800 wild-collected *Paphiopedilum* orchids for sale; the plants had been brought into South Africa in contravention of CITES provisions and South African import regulations. At least two of the smuggled species are believed to be facing extinction as a result of overcollection in their natural habitats.

According to Marshall (1993), commercial collecting of rare species from the wild has the greatest potential to push a plant species to extinction. Commercial collecting tends to be highly selective: individual species are targeted, and entire areas searched with the objective of gathering as many plants as possible. In the worst cases, entire populations of plants can be eradicated from an area. Furthermore, according to Jenkins & Oldfield (1992), people who collect wild plants for commercial trade are usually paid very low salaries. It is likely that this encourages them to collect as many plants as possible in order to maximize their income. Overcollecting and the loss of species diversity in the wild are the most compelling reasons for promoting artificial propagation of threatened plants, a process known as ‘conservation by cultivation’, for sale to collectors and other consumers.

Conservation by cultivation

‘Conservation by cultivation’ is a term that has different meanings for different people. Some collectors hold the view that they are helping to conserve threatened plants simply by ‘cultivating’ them in their collections. However, this is not, strictly speaking, ‘conservation’ because plants in collections are isolated from the natural gene pool; their genes do not contribute to the evolutionary process that allows species to survive in a world requiring genetic diversity to meet ecological challenges. In addition, rare plants in collections are not part of the species’ natural habitat and any artificially propagated offspring are unlikely to be used to recolonize wild populations. Recolonization programmes are most effective when they are established in the country where the plants are indigenous. To maintain credibility, recolonization programmes have to be scientifically managed to ensure that diseases are not introduced to wild populations and that the purity of species is maintained.

TRAFFIC’s research indicates that the trade in South African plant species is larger than previously thought. Fortunately, South Africa has a large and well established nursery community who artificially propagates many of the plant species exported or sold on local markets, and its activities pose little threat to wild populations. The most productive conservation action a collector of rare plants can take, is to artificially propagate plants and to make the offspring available to local collectors, thus reducing the demand for wild-collected specimens. Artificial

propagation of indigenous species is an important activity and a sustainable source of income for many people. In recent years, there has been argument about what constitutes true artificial propagation and what is truly of wild origin. After much deliberation CITES agreed to the following definitions:

1. The term 'artificially propagated' shall be interpreted to refer only to plants grown from seeds, cuttings, divisions, callus tissues, or other plant tissues, spores, or other propagules under controlled conditions.

   'Under controlled conditions' means in a nonnatural environment that is intensively manipulated by human intervention for the purpose of producing selected species or hybrids. General characteristics of controlled conditions may include but are not limited to tillage, fertilization, weed control, irrigation, and nursery operations such as potting, bedding, and protection from the weather.

2. The cultivated parental stock used for artificial propagation must be:

   established and maintained in a manner not detrimental to the survival of the species in the wild;

   managed in such a way that long-term maintenance of this cultivated stock is guaranteed.

3. Grafted plants shall be recognized as artificially propagated only when both the rootstock and the graft have been artificially propagated.

Trade controls and legislation

In spite of attempts to put plant conservation on a sound, rational basis, current national and international trade controls are subject to much discussion and controversy. During interviews with plant traders in South Africa, criticism was directed primarily at the disjointed and confusing nature of current conservation legislation. CITES controls were also criticized. Some dealers regarded CITES controls and provincial conservation laws as unfair and time-consuming and they admitted that they tried to avoid them wherever possible. With regard to CITES, this stand was often based on a perception that the Convention was there to stop all trade in wild plants and therefore to cripple legitimate business. To the contrary, CITES does not prohibit trade in plants that are not internationally recognized as endangered species. The Convention is based on the belief that responsible resource utilization is a means to achieve conservation.

Special interest groups should regulate the actions of their members by adopting a code of ethics which preclude the collection, exhibition or sale of wild-collected plants at flora shows. The exhibition of artificially propagated plants should be encouraged instead. Some South African specialist societies, despite the fact that they promote the collection of rare species, often have no ethical guidelines in their constitutions. A result is that some members, even committee

members, become passively or actively involved in circumventing trade control regulations to obtain certain rare species. The responsibility to conserve plant species, common or rare, rests with all wildlife consumers and requires cooperation between those charged with conserving biodiversity and those who wish to utilize the earth's biodiversity for their own ends.

An aspect of the plant trade currently on the increase in developing countries, is the commercial use of plants or plant extracts by local or foreign commercial enterprises. The use of *Prunus africana* or red stinkwood as a source of unique pharmaceutical chemicals is a current example (Barker *et al.* 1994). The creation of markets for the bark of this species has placed unsustainable demands on its wild populations. There is a need for formal conservation and trade controls to prevent the loss of biodiversity wherever individual species are targeted for commercial use, either locally or internationally.

CONCLUSIONS

The man in the street, plant dealer, scientist or traditional medical practitioner may feel that his or her commercial, private or medicinal use of plants makes an insignificant contribution to the South African plant trade. However, accumulated trade figures from individual plant dealings can be large and in some cases can threaten the survival of species.

The results of research done by TRAFFIC indicate that most of the South African plants traded internationally are not listed on CITES. A smaller component of the trade comprises plant species listed on CITES Appendix II, and for which the trade is theoretically legal under CITES. The size of the illegal component of South Africa's plant trade remains to be quantified.

In South Africa, an increasing number of people are being made aware of conservation and environmental issues. The reasons for this are variable but are basically some combination of increased awareness of economics, ethical considerations, and legal constraints (due to enforcement). Awareness has been created as a result of increased media coverage and through the efforts of conservation organizations, plant societies and botanical gardens to educate the plant-buying public. As a result many plant consumers and propagators are moving away from the use of wild-collected plants to artificially propagated stock. Unfortunately, amongst the other groups in the plant market, an atmosphere of apathy or planned defiance exists towards measures that control trade in plants with the objective of achieving sustainable and ethical use of natural resources. Continued efforts are required to educate these groups or to take appropriate law enforcement measures.

It is important to remember that a large group of South Africans depend on wild-collected plants for food and medicine. To these people the value of the plant lies not in its preservation for the sake of conservation, but in its ability to provide shelter, food, medicine or pesticides and in its other practical uses. In the past,

laws have not adequately recognized the traditional use of plant resources, with the result that these activities have been, and still are, regarded as illegal. However, increasingly a more pragmatic view is being taken of traditional plant use. Research into traditional indigenous plant use by South Africans needs to be encouraged to ensure that this aspect of plant trade is sustainable and does not threaten the survival of species.

Current South African conservation legislation is viewed by traders and consumers alike as being either sufficient, excessively strict, too lax, confusing or unenforceable. The reasons given to explain these criticisms range from lack of manpower for enforcement, to excessively rigid interpretation and implementation of laws, to deficiencies in conformity between provincial ordinances. These criticisms often have merit but need to be investigated taking into account the sometimes complex agendas behind accusations.

Many people are still not aware of or interested in the origin of the plants they buy or trade in. Some may unwittingly become involved in the illegal plant trade simply by buying a mature cycad from the roadside without first checking to see if it was legally obtained by the vendor. By refusing to support the illegal trade, the artificial propagation of rare plants is encouraged and this in turn helps to reduce collecting pressures on plants in the wild.

For all those consumers of plants or dealers in plants who are concerned about the overexploitation of plant resources, the following guidelines may be useful:

1. Before buying a flower bulb, look for information about its source.
2. Critically evaluate the information about plant origins.
3. If there is any ambiguity, question the nurseryman or vendor.
4. Consider growing plants from seed rather than purchasing plants of uncertain origin.
5. Voice your concerns.
6. Be aware of national legislation protecting plants.
7. When in doubt, contact the botanical gardens (the National Botanical Institute) and other conservation organizations to determine which nurseries or vendors sell propagated plants.

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Conservation of plant genetic resources in southern Africa

H. MOSS
Roodeplaat Grassland Institute, Private Bag X05,
Lynn East, 0039 South Africa.

ABSTRACT

A status report on the conservation of plant genetic resources in southern Africa is presented, in the context of global genetic resources initiatives. The role of the SADC Regional Gene Bank is outlined, and South Africa's links with this organization are discussed. The potential value of southern Africa's genetic resources as a reservoir of unusual genes for use in breeding and improvement programmes is discussed. Implications of the Convention on Biological Diversity for the conservation and utilization of genetic resources are detailed, and the possible consequences of the changing situation are outlined. An account is given of the threats posed by the sovereign rights movement to the accessibility of genetic resources as well as to the future food security of South Africa and the rest of the region. The possibility of turning the situation to the region's advantage is discussed. Some of the issues relating to intellectual property rights and the ownership of genes are touched upon.

DEFINITION OF PLANT GENETIC RESOURCES

In the past the term plant genetic resources referred only to the genetic material of the major agricultural crops and their primitive cultivars, land races and wild and weedy relatives. More recently, however, the concept has been broadened to include forages, medicinal plants, horticultural crops, traditional wild foods and, in fact, any plant germ plasm that contains characters of actual or potential value (IBPGR 1991). Since potential value is difficult or impossible to assess, given our present knowledge base, the term plant genetic resources is open to interpretation and can be as broad or as narrow as the needs of the conservator or user.

Plant breeders need a constant supply of basic genetic material in order to keep up with the demand for new resistance systems, new environmental tolerances, higher yields and improved resilience (Plucknett *et al.* 1987). A variety that has taken 10 to 15 years to breed may have a useful life of only three to five years. Hundreds of genotypes and thousands of individuals may have been screened and rejected in the making of that variety. Thus it can be seen that genetic resources underpin agriculture, and that the world's food security is entirely dependent on a continuous and unimpeded supply of this material.

IMPLICATIONS OF THE RIO CONVENTION FOR FOOD SECURITY AND THE AVAILABILITY OF PLANT GENETIC RESOURCES

At the Rio Earth Summit in June 1992 the issue of biodiversity and genetic resources was a prominent topic on the agenda, culminating in the drawing up of the International Convention on Biological Diversity (UNEP 1992). This is considered to be a benchmark treaty in that it grants legal recognition to the issue of sovereign rights to genetic resources. In other words, genetic resources are now considered to be the legitimate property of the country in which they originated. It follows that the country of origin has the right to determine who may use its genetic resources and for what purpose. That country also has the right to demand financial returns from its material (Reid *et al.* 1993). This treaty therefore recognizes the financial as well as the strategic value of genetic resources. The implications of this Convention are potentially serious for southern Africa for the following reasons:

1. By recognizing sovereign rights, the Convention has made genetic resources less accessible on an international scale, and potentially far more expensive. In other words ‘free’ germ plasm is a thing of the past, and germ plasm is generally no longer freely available, nor free of charge.
2. Since southern Africa does not lie within the centre of diversity or origin of any major crop plant—with one or two minor exceptions—the region is almost totally dependent on a constant supply of germ plasm from elsewhere. Restrictions imposed by the countries of origin of the genetic material could lead to an agricultural problem of serious dimensions. Germ plasm is now considered to be a strategic resource.
3. Because access to genetic material will now be more complicated and probably more restricted than previously, biotechnology companies, the pharmaceutical industry, plant breeders and other users will be looking for new sources of material that are easily accessible. Southern African countries represent such sources. Being a signatory to the Convention does not automatically give protection to a country’s biodiversity or genetic resources (Reid *et al.* 1993). It is incumbent upon each member state to ensure that it has control over what material leaves the country. Apart from a small number of specifically protected species, there appear to be few or no restrictions on the export of germ plasm from southern African countries at present.
4. South Africa possesses some 22 000 indigenous higher plant species; this places it third highest in plant species diversity of all countries in the world, after Brazil and Indonesia. This means that South Africa will be an extremely attractive prospect for foreign institutes seeking new material. Unless rapid steps are taken to protect its genetic resources in some way, South Africa may stand to lose an enormous resource.

THE IMPORTANCE OF SOUTHERN AFRICA FROM A GENETIC RESOURCES VIEWPOINT

It is necessary to establish clearly the importance of southern Africa's genetic resources to the broader world. What indigenous genetic resources does the region possess? What biodiversity does southern Africa have that the rest of the world needs? What does the region have that could be used as bargaining chips in the international genetic resources arena?

Germ plasm from extreme environments

Firstly, the region has extreme environmental gradients. The harshest habitat types of southern Africa may be viewed as untapped reservoirs of germ plasm with exceptional environmental resistance and tolerance traits. Since a major focus of future breeding programmes will be the development of high-yielding lines adapted to marginal and harsh environments (Hoyt 1988), material from these areas is likely to be in high demand. There is a proven correlation between environmentally tolerant genes and genotypes, and the habitat regime from which they originated. This correlation can be used predictively in adaptive breeding programmes. Of particular importance is the relatively high genetic integrity of much of the material in these environments. This is due to the fact that land pressures tend to be lower in southern Africa than in comparable environments elsewhere in the world. An important contribution to these breeding programmes is likely to come from wild species already in these environments.

The following are examples of the harsh environments of southern Africa, from which valuable and often unique genetic resources may be obtained:

The Afroalpine and Afromontane regions of Lesotho

The vegetation of these areas is able to withstand extreme conditions of frost-heaving, snow recorded from every month of the year, severe physiological drought, high insolation levels, strong winds, considerable grazing pressure and depauperate, leached, acid soils (Jacot Guillarmod 1971).

Desert and semidesert areas

The Namib and Kalahari systems are characterized by high aridity, temperature, ultraviolet and salinity levels, as well as nutrient-poor soils. It is possible that genotypes adapted to desert conditions may possess a greater degree of genetic plasticity than populations of the same species growing in more favourable environments. These genes may be able to confer traits of high adaptability to commercial forage and crop lines. Drought-adapted genotypes and species are able to grow and proliferate under an erratic and unpredictable rainfall regime and an extreme temperature regime. A number of species used as commercial forages of major international importance are indigenous to the Kalahari (Figure 1).

Figure 1.—Collecting *Anthephora pubescens* in the Kalahari.

Saline areas

The inland halophytic zones of southern Africa, namely the Makgadikgadi (Figure 2) and Etosha Salt Pans as well as other smaller saline areas, are characterized by high salinity, high reflection and insolation levels, and extreme aridity. The Etosha Pan supports sizeable herds of migratory game, pointing to a moderately high seasonal productivity of the vegetation. Salt-tolerant species and genotypes may well be able to improve productivity levels in the many hot semi-arid areas of the world currently affected by agricultural salinization.

Areas with high levels of incident ultraviolet radiation

Even small increases in the quantity of ultraviolet radiation have been shown to inhibit or even stop the sexual reproductive capacities of plants. Because levels of absorbed ultraviolet radiation penetrating the atmosphere are expected to increase due to the hole in the ozone layer, adaptation to higher levels of this type of radiation will be of increasing importance as a character to be transferred into commercial forage and crop lines. Certain areas of the Namib Desert are believed to receive particularly high levels of ultraviolet radiation on a constant basis, as are high-altitude areas such as the montane regions of Lesotho.

Areas with nutrient-poor soils

Large areas of southern Africa are covered in nutrient-poor soils. Crop and forage genotypes adapted to and productive under nutrient-deficient conditions, particularly the low phosphate levels characteristic of Kalahari sands (Leistner 1967), are in great demand for enhancing productivity elsewhere in the world.

Acid soils in arid environments

Acid sand pockets occur in the region of Walvis Bay, as well as in small isolated pockets of the Kalahari. Range or forage species adapted to acid soils in an arid environment are rare and in great demand elsewhere in the world (R. Reid pers. comm.).

Other germ plasm of importance

Apart from germ plasm with adaptations to extreme environments, there are other plant groups in southern Africa that contain important genetic resources.

Floricultural material

South Africa's indigenous ornamental flower species represent a vast untapped resource of inestimable financial value. The flower trade is expanding

Figure 2.—The Makgadikgadi Salt Pans, the source of important salt-tolerant genotypes.

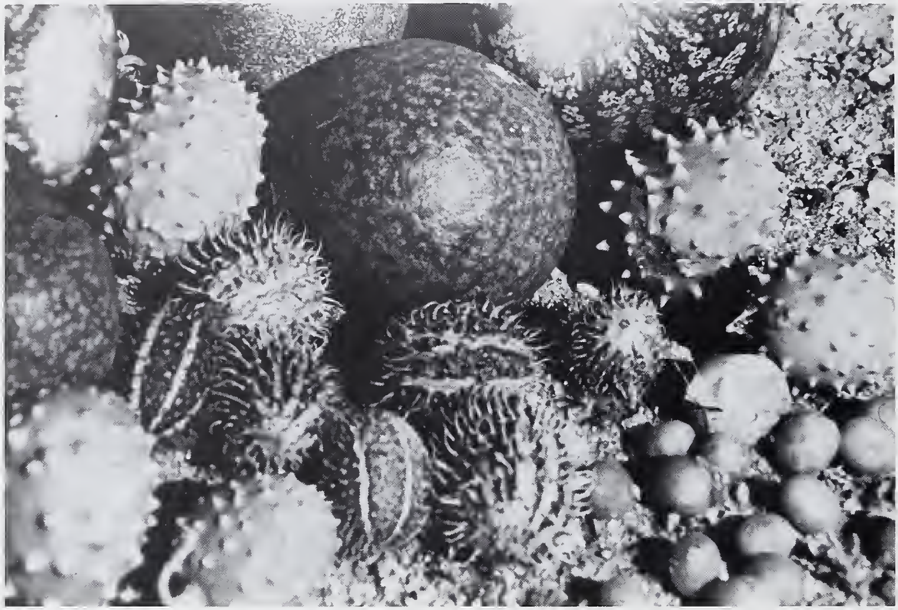

Figure 3.—A diverse array of cucurbits collected from one small area of the Namib Desert.

rapidly around the world and new cut-flower and potplant types are in constant demand.

Commercially important forages

Southern Africa is the source of many forage genotypes of considerable international economic importance. Most of the considerable range of indigenous species and genotypes have not yet been evaluated for forage characters.

Centre of diversity of certain Cucurbitaceae

The Kalahari and Namib Desert systems represent a major centre of diversity for certain members of the Cucurbitaceae, and species and genotypes from these areas could be used in drought-adaptation breeding programmes for cultivated cucurbits (Figure 3).

Centre of diversity of the cowpea

Southern Africa represents the centre of diversity of the cowpea. The cowpea is an important staple crop in certain parts of Africa as well as elsewhere in the

world. The crop has a highly restricted gene pool, which has for many years frustrated attempts at breeding better adapted cultivars. The few taxa thought to occur in the primary gene pool are found only in southern Africa (Maréchal *et al.* 1978) and have not yet been available for use in breeding and improvement programmes.

Isolated genotypes

A number of crop groups with outliers from the primary centre of diversity have wild species occurring in southern Africa. These species have effectively evolved on biogeographical islands, both geographically and genetically isolated. As such they represent an extremely important genetic resource, of interest to breeders from the point of view of crop gene pools. The following genera are included: *Trifolium, Hordeum, Sorghum, Corchorus, Leersia, Ricinus, Lotononis, Pennisetum.*

Primitive crops

Primitive crops still occur in certain parts of southern Africa, usually in areas isolated by war, politics or geography. Examples would be maize in Angola and primitive rice in Madagascar. The maize in certain parts of Angola may be directly descended from that thought to have been brought by the Portuguese centuries ago. When the first settlers arrived in Madagascar from Polynesia in about 600 A.D., they brought with them the primitive rice land races they were growing at the time. These flourished in Madagascar and became adapted to the local environments. Many of these cultivars are still grown in Madagascar today, and have not yet been displaced by modern varieties due to the geographical and political isolation of the country (Denton 1984).

Desert genotypes susceptible to global warming

The effects of global warming cannot be accurately predicted yet, but it is considered likely that southern Africa's deserts and semideserts may be adversely affected (Jansson 1991). Many desert species are already growing at the extreme limit of their tolerance ranges. Even a small increase in temperature or long-term aridity may therefore induce a genetic shift and alter or compromise the gene pool, or even result in extinction. Should this prove to be the case, the arid and semi-arid environments of southern Africa may be vulnerable.

REGIONAL GENETIC RESOURCES CONSERVATION INITIATIVES

Genetic resources in southern Africa have until recently received little attention. Because the region does not lie within one of the Vavilovian Centres of Origin (Ford-Lloyd & Jackson 1986), it was not initially considered to be of importance from a genetic resources point of view.

During the latter part of the 1980s, national plant genetic resource programmes were established in many countries of the world, including the developing world. In several instances regional alliances and networks were formed to strengthen the genetic resources bases of the countries within the regions, and to increase the self-sufficiency of regions with respect to their requirements for genetic resources.

In 1987 a regional genetic resources programme, known as the SADC (Southern African Development Community) Regional Gene Bank (SRGB) was established under an international aid programme, with its headquarters just outside Lusaka. It covers the ten SADC countries, i.e. the countries south of and including Tanzania, but excluding South Africa. A primary function of SRGB is to assist each of the SADC member states in setting up a National Plant Genetic Resources Programme, each of which would function as an integral part of the Regional Programme. One of the objectives of this programme is to assist in attaining sustainable development of agriculture and forestry in the region. By attending to needs for genetic resources on a national rather than global basis, it is hoped that local food security will be improved.

The SRGB programme has several elements. It assists countries in laying the foundations of a national genetic resources programme by lobbying for the inclusion of a genetic resources budget in the appropriate ministry. It also assists in the construction or modification of a gene bank and the necessary offices and laboratories. Much of the necessary equipment is provided to each country by the programme, including deepfreezes, a four-wheel drive vehicle and laboratory equipment. The SRGB also sponsors trainees at various levels, from short technical courses to master's degrees. Funding comes from the five Scandinavian countries, with technical and training input from IBPGR (SIDA 1989). It is anticipated that funding will be provided by the Nordic countries for a 20-year period, with the countries themselves taking over 10% of the payments from year 10, increasing incrementally to the final year when it is hoped that the programme will be fully funded by the member states.

The national programmes are currently involved in making inventories of the genetic resources priorities in their countries. Gene banks have been established in most of the countries, and personnel are being trained. To date very little collecting has been undertaken by the programmes themselves.

SOUTH AFRICAN GENE BANK

The development of the SRGB took place during the time when South Africa was isolated from most of the rest of the world. Consequently, the country has been largely excluded from regional and international activities but it is expected that this situation will change in the near future. It is likely that South Africa will soon be incorporated into SADC, and when this happens South Africa will be in a position to join the regional genetic resources programme to the benefit of all

parties. With its history of high-quality botanical exploration and field work, South Africa has much to offer the region in setting an example.

Genetic resource conservation efforts in South Africa have been poorly coordinated and inadequately supported. In the 1940s and '50s, parts of the country were explored for forages, and some of these genotypes are now of major commercial importance in a number of countries around the world. This work was of international significance. The original accessions were located at Rietondale Experimental Station in Pretoria, but due to financial constraints and a lack of understanding of their importance on the part of the policy makers, were later abandoned.

More recently, a forage collecting, conservation, evaluation and selection programme has been initiated at Roodeplaat Grassland Institute (RGI) outside Pretoria, one of the constituent institutes of the Agricultural Research Council. The Vegetable and Ornamental Plant Institute (VOPI), also part of the Agricultural Research Council, has undertaken a significant amount of breeding and selection of ornamental horticultural material using indigenous genetic resources. Their material is stored in several field gene banks. The other commodity centres of the Agricultural Research Council all have substantial collections of germ plasm supporting their active breeding programmes. However, without exception these gene banks comprise exotic germ plasm of imported agricultural crops and crop relatives. In addition, they constitute active rather than base collections, and in some instances are not maintained beyond the point where they are required in breeding programmes. In other words, they do not fulfil the function of base repositories of germ plasm being stored for long-term conservation purposes.

The Department of Agriculture has a gene bank which falls under the auspices of the Division of Plant and Quality Control. In the past, subsamples of most seed material imported into the country via this division were retained in the gene bank. The staff of this Division have recently made a limited number of collections, including some indigenous material. However, it is believed that a proportion of the material maintained in this gene bank has not been adequately maintained and regenerated over the years and is now inviable (M. Pelser pers. comm.), or of a viability low enough to compromise the genetic integrity of the material.

Some years ago the Bolus Herbarium of the University of Cape Town made collections of a small number of endangered fynbos species. The National Botanical Institute was involved in the collection of a few hundred accessions of traditional millet, sorghum and cucurbit cultivars. The latter material was unfortunately stored under inappropriate conditions (T. Arnold pers. comm.) and it is doubted whether it has maintained its viability.

In summary, Table 1 shows the collections of indigenous material that exist in *ex situ* collections in South Africa. The figures refer to collections in conventional gene banks and exclude living collections and material in botanical gardens.

Assuming that each of the 941 indigenous species conserved has been well maintained and is still viable, which is unlikely, then this number represents only 2.5% of the indigenous species of South Africa. In addition, there is likely to be a certain amount of overlap between the species held in the various collections, lowering the number of species and the percentage.

Apart from these initiatives, which have been sporadic and lacked cohesion and coordination, little else has been done with respect to conservation of genetic resources in South Africa, and no formal policy or programme exists as yet at national or any other level.

COSTS OF *EX SITU* VERSUS *IN SITU* CONSERVATION

The main argument given in South Africa for not becoming more than peripherally involved in the *ex situ* conservation of genetic resources, is that the costs are prohibitive. Table 2 gives an idea of the costs involved. A spread of gene banks has been used, giving a wide range of costs.

In Table 2, the only type of conservation being considered is conservation in a conventional seed bank or gene bank. This storage method is applicable to all orthodox species, in other words species of which the seeds can be stored under very cold and dry conditions, usually at –18°C and 5–6% relative humidity (Plucknett *et al.* 1987). Since most of the species in South Africa are nontropical, they are likely to be orthodox in their behaviour and could therefore probably be stored in this way. There are various other types of *ex situ* gene banks such as botanical gardens, field gene banks and arboreta (Ford-Lloyd & Jackson 1986), but these are not considered in the model below.

A gene bank of 100 m^3 holds approximately 12 000 accessions (J. Hanson pers. comm.). South Africa possesses approximately 24 000 indigenous species, and it is assumed here that most of them are orthodox in their behaviour. If, as a starting point, one aims for the *ex situ* conservation of four accessions or four populations per species, one would be looking at the storage of 96 000 accessions. This would require approximately 800 m^3 of cold room or deepfreeze space.

TABLE 1.—*Ex situ* collections of indigenous material in South Africa

Institution	Total accessions	Indigenous accessions	Total species	Indigenous species
Department of Agriculture	1 584	628	1 019	402
Roodeplaat Grassland Institute	3 937	1 450	320	123
Vegetable and Ornamental Plant Institute	2 681	2 681	392	392
Bolus Herbarium	39	39	24	24
TOTAL	8 241	4 798	1 755	941

TABLE 2.—Cost of *ex situ* conservation per accession per year

Gene bank		Cost per accession per year in Rands
PGRC/E	(Ethiopia)	16 >
CIAT	(Colombia)	54 >
ILCA	(Ethiopia)	100
CG System	(17 gene banks around world)	134
RGI	(Pretoria)	149
Kew	(England)	370

(Sources: J. Toll, J. Hanson, S. Linington, A. Kruger pers. comms)

If accessions are stored, maintained and occasionally regenerated at an average cost of R100 per accession per year (estimated from Table 1), the long-term storage of 96 000 accessions would cost R9.6 million annually. This would allow the conservation and secure maintenance of the total orthodox plant species diversity of South Africa, as well as a good spread of the available genetic diversity.

DISADVANTAGES OF *EX SITU* AND *IN SITU* CONSERVATION

When looking at the financial costs of *ex situ* conservation, one also has to look at the costs in other terms. There are certainly many disadvantages to *ex situ* conservation, and it is not being advocated as the solution to all South Africa's conservation problems. But *in situ* conservation also has a number of significant drawbacks. In fact, both types of conservation have their disadvantages, and these are briefly listed below.

Disadvantages of ex situ *conservation in a conventional gene bank*

- It provides a limited snapshot of genetic diversity relative to the total gene pool.
- Evolution is effectively stopped.
- Genetic shift and drift may occur in multiplication cycles, thus compromising genetic integrity.
- Material conserved in this way is vulnerable to poor gene bank management practices.
- Very little is known about the long-term conservation of most wild species. Such conservation initiatives would therefore have to go hand in hand with research on seed physiology, germination, dormancy breaking and so on.

Disadvantages of in situ *conservation*

- It is vulnerable to natural disasters such as pests, fires and storms.
- It is vulnerable to political whims and ever-increasing land pressure.
- It is becoming rapidly more expensive to manage and protect natural areas.

- The material conserved in this way is to a certain extent inaccessible to researchers and users.
- It is possible to conserve only limited numbers of species and genotypes per area.
- *In situ* reserves are susceptible to global warming, which could take the form of genetic shift or of species or genotypes disappearing.

Although it is hoped that *in situ* conservation will continue to play the major role in any and every conservation strategy, one has to be realistic about the uncertainty of the long-term survival of such areas. Underwriting *in situ* conservation with a basic *ex situ* conservation strategy seems a sensible and relatively inexpensive precaution to take, and part of a fundamental pre-emptive conservation strategy.

CONCLUSIONS

It has been argued above that there is a potentially risky situation developing in the international genetic resources arena with respect to international availability of germ plasm. It has also been suggested that South Africa and other southern African countries could be rather vulnerable.

However, there might be a way around this. With many countries effectively closing their borders to the export of any germ plasm, South Africa could do just the opposite. The country could become known as a source of a wide range of accessible and available germ plasm which can be used by any interested party *provided* that South Africa is able to share in any benefits derived from the use of that indigenous material. If we are able to create a demand for South African genetic resources for use in research, breeding and screening programmes elsewhere in the world, it will give the material an intrinsic value, justifying its continued conservation. The most important aspect of this strategy will be the standard and compulsory documentation that accompanies the export of all South African plant material, legally obliging the user to profit-sharing should any part of that material be used in a commercially successful venture. If properly executed, this should ensure a steady two-way flow of germ plasm to and from South Africa. In order for this approach to be successful, South Africa will have to present a united front, and every player in the genetic resources field will need to be involved in order to ensure its success. This points to the need for coordination at national level.

The advantages of South Africa establishing a national genetic resources policy and programme are as follows:

1. It will be possible to adopt a controlled but open-door genetic resources policy at national level.
2. It will help to ensure the future food security and agricultural base of South Africa.

3. South Africa will have increased access to genetic resources from all over the world, and reciprocal genetic resources agreements.
4. The country will obtain credibility and acceptance into the international genetic resources community.
5. With the vast range of plant genetic resources which South Africa possesses, there is tremendous scope for their development, in partnership with other countries, and a chance of extremely lucrative returns.
6. Financial returns from the use of our indigenous plant genetic resources should provide an economic justification for the continued conservation of this resource in the long term. There have been continued calls to reassess the economics of biodiversity conservation, and this is one way in which the conservation of biodiversity can pay its way.

It is obvious that these conclusions apply equally to any other southern African country wishing to create a situation in which its genetic resources develop market value.

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THE WORKSHOP
A BOTANICAL DIVERSITY NETWORK FOR SOUTHERN AFRICA

Brian Huntley

INTRODUCTION

The recent emergence of biodiversity as an issue of global importance has resulted in a plethora of symposia, a rush of international travel and a new lexicon of jargon. On the positive side, some excellent syntheses of the nature and causes of the 'biodiversity crisis' have been published, and ambitious strategies and action plans prepared. As is so frequently the case in conservation matters, the botanical component of the biosphere has been neglected. This is particularly so in southern Africa, despite several recent meetings on biodiversity in the region.

In order to redress the situation, a postconference Workshop was convened at Kirstenbosch National Botanical Garden, Cape Town, with the primary goal:

> *To develop a common vision of the challenges and opportunities relating to the conservation and utilization of southern Africa's botanical diversity, and to explore ways in which the region's botanists may contribute to ensuring the sustainability of this resource.*

THE WORKSHOP PROCESS

The Workshop was structured in a manner to draw as fully as possible on the knowledge and experience of the more than 80 participants. The Workshop concentrated on its interactive *process* rather than on the preparation of an elegant report. The most important product of the Workshop would be the establishment of a common vision for southern African botany, setting new tasks, achievable action plans and drawing regional expertise together within an 'invisible college' of collaborating workers.

The Workshop focused on a set of key issues or needs relating to 'knowing, saving and using' botanical diversity. The topics, within the three main themes, were:

Know it

- Systematics and biodiversity.
- Measuring and monitoring plant diversity.

- Herbarium management and networking.
- Information and data management.
- Capacity building: training and education.

Save it

- Species-level issues and actions: *Red data books*, rescue and restoration, etc.
- Ecosystem-level issues and actions: protected area networks, gap analysis.
- International conventions and action programmes.

Use it

- Plant use: medicinal, structural, craft users, etc.
- Plant genetic resources.

For each of the ten topics selected, the Working Groups examined the following aspects:

- *Where are we now*—what levels of information, understanding, action, facilities, human resources, etc. do we currently have at our disposal on this topic?
- *Where do we want to be*—what are the goals that we can set to achieve, through sharing our skills and resources, by the year 2000?
- *How do we get there*—what action steps can we initiate ourselves, or with outside support, to reach our goals?

Topics which have previously been exhaustively described in the literature were excluded from the Workshop agenda. These included:

Values of biodiversity.
Threats to biodiversity.
National policy frameworks.
Philosophical issues: ethics, intellectual property rights.
Funding sources.
Rangeland management.
Recreational use.

WORKSHOP REPORT AND CONCLUSIONS

Each Working Group prepared and presented, in a series of iterations, reports on their findings. The format of submissions varied from one Working Group to the next, but the message that emerged from the process was clear and important, and can be summarized as follows:

- Southern Africa has an extremely rich, but in some areas poorly researched botanical diversity.
- Most countries in the region have very few trained botanists in permanent posts, few have more than rudimentary facilities.
- As a whole, however, southern Africa possesses the human resource potential in biology to make a meaningful contribution to the study, conservation and use of its botanical diversity.
- This potential could be best developed and strengthened through the formation of a regional network of botanists.
- A mechanism must be established, with appropriate funding, to ensure that the urgent capacity building and infrastructural support needed to mobilize the region's latent potential is realized.

WORKING GROUP 1
SYSTEMATICS

CONVENER: Charles Stirton
PARTICIPANTS: Augustine Chikuni, Roger Ellis, Saskia Hobson, Peter Phillipson, Gideon Smith, Janine Victor, Rosemary Williams

INTRODUCTION

Taxonomy is basic to all biologically related research and much of human endeavour. It provides identification services, predictive classifications, stable nomenclature and a framework of ancillary data useful to many other disciplines. The synthetic nature of taxonomy, its multidisciplinary focus and its phylogenetic underpinning do much to promote an effective base for the sustainable use of plant resources. However, the image of taxonomy in the region is weak and there is a poor understanding of the benefits which can be derived from taxonomy. What is the state of the discipline in southern Africa today and how can it contribute effectively to preserve biodiversity?

WHERE WE ARE NOW?

In botany, taxonomy is the science concerned with the identification, nomenclature (scientific naming) and systematic classification of plants, both living and extinct. It provides a reference system and means of communication to deal with the enormous diversity of the plant kingdom. Clearly, the reliability of botanical research in any field is indissolubly linked to the availability of a sound taxonomy. Evidence suggests that there are not enough plant taxonomists available in southern Africa to provide the services required by the users of taxonomic products. In the subregion, South Africa has the largest number of practising taxonomists, with an estimated 40 to 50 individuals occupying full-time positions. Most of them have various other duties besides research, e.g. plant identification and curatorial activities (state institutions), or lecturing responsibilities (tertiary education). In other southern African countries the situation is far worse; for example in Angola there are no plant taxonomists currently employed.

Although taxonomists usually have modest requirements for capital equipment, access to light microscopes (dissecting and compound) and electron microscopes (scanning and transmission) is usually necessary. However, the support structure and facilities, like the availability of professional expertise and

basic equipment, are insufficient, ranging from excellent to nonexistent across the region. Sound taxonomic research also requires access to naturally occurring plant populations, a specialist botanical library and herbarium collections. Funding for field research and visits to foreign (mainly European) herbaria, where most pre-twentieth century work on southern African plants was carried out, is generally insufficient.

This chapter considers the key issues which need to be addressed to remedy the situation, the role of taxonomists and taxonomy in the region, and future prospects of systematics in southern Africa. Key issues include:

- Clearer definition of user requirements (type of information, format of products, *Red data* information, etc.).
- Contribution of taxonomy towards identifying commercial opportunities for biodiversity (horticulture, timber, crop resources, pharmaceuticals, etc.).
- Expansion of skills base and support services (training, herbaria support and information, parataxonomy, etc.).
- Promotion of all branches of taxonomic expertise (checklists to molecular systematics).
- Programme of regional priorities and interests set locally.
- Sensitization of taxonomists to needs of users.
- Creation of job opportunities for taxonomists.

WHERE DO WE WANT TO BE AND HOW CAN WE GET THERE?

The Working Group recognized two primary goals to be reached by the year 2000: first, to find out what users of taxonomic products require and for taxonomists to inform users of data available (ongoing), and second, to determine and attain a critical mass of plant taxonomists within the 10 countries of the region by the year 2000.

The achievement of these goals would be approached through a programme of seven activities, each discussed in the following sequence: action plan, timetable, who should get the feedback, performance indicator and general comments.

Activity 1
Find out what users of taxonomic products require

- Action plan: user task groups to be recognized and established (e.g. horticulturists, ecologists, conservationists, amateurs, ethnobotanists, taxonomists etc.).
- Timetable: 1993–1994
- Who should get the feedback: primarily all plant taxonomists in the region and abroad wherever appropriate.
- Performance indicator: booklet or published paper with priorities indicated, modification of guides to authors, journals, etc.
- General comments: we need to identify different target groups of users throughout the region. Currently systematists provide information on distributions, diagnostic descriptions and illustrations, uses, nomenclature, literature, ecology, life form, habitat, phenology, breeding systems, conservation status, vernacular names, etc.

Activity 2
Compile a checklist of plant species of southern Africa

- Action plan: coordinate a programme amongst all southern African herbaria wishing to participate. Harare Herbarium (SRGH) and National Herbarium (PRE), being the largest herbaria in the region, need to play a key role.
- Timetable: 1993–1999.
- Who should get information: every botanist or layperson interested in the flora of the region.
- Performance indicator: book(s) and electronic availability of information.
- General comments: a priority would be to computerize SRGH. PRECIS should be expanded to include other centres. The checklist will enable country subsets (and others; regional, ecological) to be produced. This data set will be a core source of information for many different user databases.

Activity 3
Determine and attain a critical mass of plant taxonomists within all countries

- Action plan: identify needs, raise funds.

- Timetable: 1993–2000.
- Who should get information: recent surveys of the state of herbaria and of taxonomy should be widely publicized, particularly amongst donor agencies.
- Performance indicators: permanent posts in place.
- General comments: we are concerned that many taxonomists in the region are unable, for various reasons, to be productive. For this reason, we believe that taxonomic research should be supported by a competent professional team of curators, botanical artists, research assistants, adequate accommodation and equipment, access to the field and links to other research groups and specialists. Taxonomists should form an integral part of the herbarium, and should contribute to curatorial activities. Herbaria should have a balanced complement of expert and support staff.

Activity 4
Develop new ways of presenting taxonomic data to the user community (format, content, medium)

- Action plan: regional workshop(s) initially by the Plant Systematics Stimulation Programme of the Foundation for Research Development.
- Timetable: 1993–1995.
- Who should get information: general botanists and taxonomists internationally.
- Performance indicators: new types of products.
- General comments: more illustrative material should be produced, e.g. for easy identification. Courses/workshops should be held to disseminate the information. Taxonomists need to set realistic and attainable objectives, and to publish as soon as possible the large amount of unpublished work.

Activity 5
Include a broader cross-section of the population in taxonomic activity, in particular the existing amateur botany network and the traditional knowledge network

- Action plan: establish a parataxonomy programme which will link the existing amateur botany network and the traditional knowledge network to taxonomic activity. In particular the collection of specimens and the recording of data should be encouraged.
- Timetable: 1993–1995, then ongoing.

- Who should get the information: local and international community.
- Performance indicators: formal network with financial support.
- General comments: herbaria and taxonomists to work with and encourage parataxonomists, and to include their data into mainstream taxonomy. Examples of activities include the *Proteaceae Atlas* project, school projects, sight recordings, and casual identifications.

Activity 6
Establish a focused programme of plant collecting in undercollected areas in the region

- Action plan: develop local maps of collecting intensity.
- Timetable: 1993–ongoing.
- Performance indicators: improvements to checklist, monitoring of collecting intensities.
- General comments: prioritization within regions of target collecting areas should result in integrated proposals for collecting expeditions and should seek funding accordingly.

Activity 7
Establish a regional network of specialist taxonomists

- Action plan: identify specialists to provide expertise to all herbaria in the region.
- Timetable: 1993–ongoing.
- Performance indicators: more effective progress in the completion of regional floras; revisions of difficult families, genera, etc.
- General comments: for too long Africa has been dependent on the taxonomic leadership of European and American specialists. Increased local capacity must be developed to assume responsibility for and ownership of the study of Africa's rich flora.

CONCLUSIONS

The Working Group concluded that:

- These programmes will help establish a better understanding of the region's plant diversity and its future sustainable utilization, management and regional collaboration.

- An efficient, productive and coordinated taxonomic service in the region is fundamental to achieving the many and diverse goals presented by the other Working Groups.

- International collaboration and support (financial and professional) is essential to realize our goals. However, in order to ensure a sustained programme, it is vitally important that foreign involvement is harmonized with the requirements of a regional network which should be established.

- Regional monographs and monographs of endemic taxa in each region are valuable sources of data to users and generate many research and applied activities. Their publication within the region needs to be encouraged and their wider distribution and use need to be promoted.

WORKING GROUP 2

MEASURING AND MONITORING PLANT DIVERSITY

CONVENER: Peter Goodman
PARTICIPANTS: Kate Braun, Holgar Eckhart, Matt Erasmus, Dave Everard, Dave McDonald, Steve McKean, Renette Smit, Francine van Heerden

INTRODUCTION

The need to inventorize and monitor changes to plant diversity in the southern African region is well recognized by conservationists. For various reasons, however, this has not been achieved to a satisfactory level. Some of these reasons include:

- Lack of expertise and resources (financial and otherwise).
- Countrywide social disruption and war (Angola and Mozambique).
- The low priority of conservation on the political agenda.
- The lack of coordinated effort.

The Working Group accepted the first two factors as beyond their ability to influence, but identified the latter two factors as reversible in the short term.

WHERE ARE WE NOW?

We are currently at the initial stages of developing contacts across the southern African region. Biodiversity is threatened across the region and we need to establish a common vision, strategy and action plan to identify and conserve biodiversity. At this stage the availability and quality of data on the region are largely unknown.

We therefore need to establish a register/database of all information on the spatial distribution of biodiversity across the region, including, where available, simple predictive models and the current form of these models.

The results of a small survey amongst workshop participants give some indication as to the availability of inventory type data sets in the region (Table 1).

TABLE 1.—The perceived availability of data and predictive models which would be required in developing a plant diversity conservation strategy and monitoring system

	Vegetation data	Physical data	Predictive models
South Africa	Various and comprehensive	Comprehensive	Various local scale
Zimbabwe	Various	Available	None known
Mozambique	Few	Some	None known
Namibia	Various	Available	None known but possibly some
Swaziland	Various (few)	Geology available, soils—poor	None known
Botswana	Various–comprehensive	Available	Some possible?
Angola	Few–various/biome level	Some/various, geology soils	None
Lesotho	Few/some	Some	None known
Malawi	Some	Some	None known
Zambia	Some	Some/various	None known

At the outset of this programme, which aims to measure and monitor plant diversity, a much more detailed and specific register/database of available sources of physical and plant diversity data and models will have to be developed.

It is recommended that this register be linked with an organization that has regional/global interests, for example the UNEP-GRID database or with SADC.

WHERE DO WE WANT TO BE AND HOW CAN WE GET THERE?

The inventorization, monitoring and modelling of plant diversity and the impact of plant-use programmes, land use and change and urban developments on this are seen as fundamental for the future rational planning and development of this region. This is expressed in what we believe to be a *common goal* for all national and local developers of strategic conservation plans, namely:

To inventorize and develop predictive models on the spatial distribution of plant diversity across the landscape and the influence of different land uses on it.

The level of resolution should, depending on the resources and expertise, span the full biological hierarchy, namely genetic, species richness, functional type, community and biome levels. The basic products envisaged are databases, maps and simple predictive models which indicate plant diversity across the landscape, in a form that can be used by conservation, landscape and urban planners. The emphasis should be on the development of protocols for producing simple predictive models which offer short cuts to time-consuming and expensive inventories and monitoring programmes.

1. Establishment of a network

The first steps towards achieving the common goal, outlined above, should be to establish a coordinating committee that will be charged with the development of a network of collaborating scientists who are responsible for inventorizing and monitoring plant diversity. This committee should perform the following tasks:

Compile a register of people involved

- Sources of names for registration are attendants of symposia, congresses, scientific journals and government and non-government conservation and research organizations. People on the register (or any other involved in relevant research) could be invited to join local working groups, or working groups which are tackling a specific task, e.g. the development of standard protocols.

Facilitate contact and collaboration

- The committee should facilitate and encourage contact and collaboration between workers in the field. This could be through the production of a newsletter, organization of local and regional workshops and symposia.

Liaise with other relevant international and local organizations such as IUCN

Obtain and administer funds

- This committee should solicit, obtain and administer funding that would be used specifically to achieve the common goal. This will include the organization of training courses, workshops and the sponsoring of key (priority) surveys.

2. Development of standards/protocols

The second step towards achieving the common goal is the development of standard protocols for measuring biodiversity at different spatial and temporal scales. These could be as follows:

Alpha diversity

Measurements of plant species richness at a point (1 m^2) stand (0.1 ha), community and landscape levels. In addition to the 'richness' of communities, their spatial arrangement in the landscape could be important. Beta and gamma diversity should also be determined within major ecosystems and biomes.

Regional diversity

Measures of alpha, beta and gamma diversity lead to predictions. Factors that control diversity such as soil type, facilitate rapid estimates of regional diversity.

Developing predictive models

It will be impossible to inventorize all aspects of plant diversity. It is therefore imperative that protocols are established for developing simple predictive models of plant diversity using the most commonly mapped physical variables such as geology, soil, rainfall and topography.

3. Collaboration

This forms the more formal approach to attaining the common vision and then working towards the goal. The specific aim of collaboration is to develop appropriate scientific expertise which will eventually help us to attain the final products (knowledge about the spatial distribution of biodiversity across the region). The network of people involved should be encouraged to collaborate by means of the following:

Exchange of information and technology

Information, databases, etc. could be registered with the central information register and the data should be accessible to participants. This may require the establishment of formal agreements between participants. Technology, i.e. algorithms, methods, models etc., should also be exchanged. Sophisticated technologies (GIS) should be used at those centres that have them, to the benefit of those who do not have them.

Exchange of scientists and technicians

People should be encouraged to go and work with colleagues in other regions to assist with the transfer of methods, knowledge and information.

Training

Courses aimed at getting participants to a basic level of capability, should be developed.

Review meetings

Symposia, congresses and workshops should be held to formally review progress and set short-term goals. These meetings will also serve to exchange information and encourage communication and collaboration.

Methods manual

Collaboration should be aimed at the production of a manual of appropriate methods suitable for the collection and derivation of a minimum set of information and compatibility of databases.

4. Methods for measurement and monitoring

Methods range from very general and extensive to specific and intensive:

Personal/people surveys

Person-to-person methods including information exchange between researcher and sangomas, agriculture extension workers, farming community, nature conservation officers and the academic fraternity.

The rather informal methods are aimed at identifying specific areas and species that are not easily detected or have been overlooked in general surveys and which will require more detailed attention once identified.

Capturing data from available sources

Published papers, reports, maps, etc. Checklists, phytosociological studies, environmental impact reports, management plans, vegetation, soil, geology maps, land-use maps, university projects/theses (unpublished), remote sensing products, etc.

Databases

National and provincial authorities (mainly Nature Conservation), universities, biome studies, PRECIS database, UNEP-GRID, etc.

Survey methods

GRADSECT survey methodology, mapping the spatial distribution of plant associations at various levels.

Modelling

Develop simple predictive models of plant species distribution and diversity, and spatial heterogeneity using available physical data as the primary predictors.

Suitable methods for monitoring changes in species diversity include:

- Plot-based methods, i.e. permanent plots.
- Fixed-point photography.
- Censusing at the single species (e.g. endemic species), population or community levels.
- Censusing population size, structure and distribution.
- Satellite and aerial photographs.
- Transects and line-intercept methods.

Objectives would be to establish the causes of changes in species distribution and abundance by exploiting natural experiments such as fence line contrasts.

5. Inventory of people or organizations working in the field of plant diversity in southern Africa

The Working Group recommended the compilation of a directory of human and infrastructural resources: organizations, addresses (E-mail), fields of work and area, fax, telephone and telex numbers.

CONCLUSIONS

The Working Group made the following recommendations:

- Establish a list/network of all in the region interested in joining a plant diversity network during the next six months.
- Organize a workshop/field study in an area where participants can share skills.
- Organize a conference and solicit contributions towards the development of methods of inventorizing and monitoring plant diversity at all levels.

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WORKING GROUP 3

INFORMATION AND DATA MANAGEMENT

CONVENER: Trevor Arnold
PARTICIPANTS: Ashish Bodasing, Bob Drummond, Margaret Graca, James Jackalman, Steven Njuguna, Nigel Parker, Yvonne Reynolds, Mike Rutherford

INTRODUCTION

Computers play an integral part in contemporary information management. They have become an important tool in the management of botanical information, enabling easy and effective capture, access, storage, manipulation and transfer of data. Without computers, valuable botanical information could remain largely inaccessible to potential users involved with the conservation and utilization of our flora. Rapid advances in computer technology are producing increasingly more powerful computer systems with greater functionality. At the same time they are becoming progressively cheaper, making them more accessible to information managers.

WHERE ARE WE NOW?

There is a conspicuous lack of knowledge about the extent of unpublished botanical information for southern Africa. A meaningful statement in this regard would therefore be very difficult. It is nevertheless believed that a significant amount of information is held by research and other organizations who have no particular need to advertise its existence.

It is also difficult to provide a meaningful estimate about what information has already been computerized. Computerization of botanical information is generally considered to be poor, with the botanical resources of the majority of countries being largely uncomputerized. In particular, an enormous wealth of information exists in the various herbaria throughout the region, which is known to be uncomputerized and, therefore, inaccessible to the majority of potential users.

Financial and other constraints, such as a lack of manpower and computer expertise, play a major role in preventing many organizations from becoming computerized, especially where large amounts of data are involved. A lack of technical support is also a problem in many places. Selection of suitable hardware and particularly software is difficult.

The extent of computerization of botanical information varies significantly between countries, with overall coverage being relatively poor in most countries. South Africa remains one of the few countries where a number of well established databases exist, affording coverage at both the regional and national levels. Despite this, there are many important data sources still to be computerized.

WHERE DO WE WANT TO BE AND HOW DO WE GET THERE?

What is required, is a network of well maintained databases providing good coverage of the plant diversity of the southern African region. Ideally, all major databases should be electronically networked. Within each country there should be at least one database providing coverage at the national level. There is also need for a minimum dataset to be included as part of all databases.

1. Directory of existing botanical information

This will be achieved by sending a questionnaire to all known holders of botanical information. Such a directory can be used to determine the extent of existing database coverage, both at regional and international levels. It will also highlight gaps in database coverage and uncomputerized information. It is recommended that the National Botanical Institute undertakes to compile the directory, based on information gathered from participating herbaria (Table 2).

Primary gaps in knowledge and existing information not yet computerized will be identified from the returns received on the questionnaires. All organizations should be encouraged and if necessary assisted with the computerization of all existing botanical information not yet computerized. Where this is not possible, information should be made available, through formal partnerships, to other suitable organizations better able to undertake the computerization.

TABLE 2.—Information required for a *Southern African regional directory*

Subject contents/scope (concise, broad description of information held)
Key words
Producer (institute, organization)
Contact person (name, address, tel., fax and E-mail)
If not computerized, are there plans to do so (never, starting within 1, 2, 3, 4, 5, >5 years)
Full database name
Acronym
Type of information (numeric, text, graphic, bibliographic)
Time span (from year *x* to year *y*)
Area covered (primary, secondary)
Frequency of updating
Approximate size (index cards, pages, records, megabytes)
Language
External services provided
Printed products
Access (restrictions, changes)
Wide Area Network (computer)
Software used (database, other)
Additional notes
Key categories of information held

2. Computerization of herbaria

Herbaria are one of the greatest sources of botanical information. Every effort should be made by herbaria to become computerized as soon as possible. Standardization of database software is highly desirable. The need exists for the development of a simple, easy-to-use database

system for herbaria, catering for a defined minimum requirement.

The level of curation in many herbaria is poor and needs attention. Competent curators are needed to ensure that correct, up-to-date names are applied to specimens. Problems of inadequate computer facilities, expertise and training which exist in many countries should be addressed (Table 3).

TABLE 3.—Status of computerization of southern African herbaria

Country	Status
Angola	none known
Botswana	poor (PRECIS database, PRE)
Lesotho	poor (PRECIS database, PRE)
Malawi	none known
Mozambique	none known
Zimbabwe	none known
Namibia	poor (PRECIS database, PRE)
South Africa	moderate
Swaziland	moderate (PRECIS database, PRE)
Zambia	none known

The proposed minimum data requirement per plant voucher specimen includes: accession number, plant name, collector's name, collector's number, date collected, precise locality, and latitude and longitude citation (as fine as possible).

3. Data quality

There is a special need to ensure that correct plant names are applied to data and that these names are the currently accepted ones. National herbaria should be responsible for making available a list of names in current use on a regular basis or on request. Special attention should also be given to ensuring the accurate recording of spatial data. Locality data should be recorded as accurately as possible using degrees, minutes and seconds, indicating the degree of accuracy of the data.

4. Database structuring and data exchange

Database managers should make themselves familiar with international data exchange protocols and standards and, if possible, should become directly involved with the committees and working groups responsible for setting standards. Databases should be structured to store data in its smallest functional unit in order to facilitate data exchange.

5. Storing data for use by GISs

Geographical information systems (GISs) are becoming established as important tools in the plotting and analysis of spatial data. It is imperative that these systems have access to information stored in databases. To facilitate this, all data should be associated with a coordinate value expressed as accurately as possible in degrees, minutes and seconds.

6. Data access

Access to data should be made as easy and as wide as possible. Organizations should keep restrictions on data access to a minimum. At the same time, database managers should be aware of the sensitivity of certain kinds of data: medicinal plants, succulents, rare plants, for example.

As more and more botanical data become computerized by different organizations and at different locations, users will find it increasingly difficult to access all available data. Inevitably more obscure and less accessible data will be overlooked by users. A critical dataset should therefore be stored in an active and well maintained national repository to facilitate access to as complete a dataset as possible from a single reputable source.

A danger exists that computerized data linked to specific research projects will be abandoned and lost when a project is completed and terminated. It is therefore recommended that research institutions should maintain an archival database system for all research-generated data no longer in current use.

7. Standardization of software

Wherever possible, organizations should standardize on software used such as GIS and herbarium software, for example. In the case of the latter, a special need exists for a programme to be developed locally which will address the specific needs of herbaria in the region. The National Herbarium, Pretoria, with its years of experience with PRECIS (**PRE** [National Herbarium, Pretoria] **C**omputerized **I**nformation **S**ystem), which is regarded as one of the most important floristic databases in the world, should undertake to coordinate a project to develop a suitable software product.

CONCLUSION

A considerable amount of botanical information exists within the various botanical institutes, herbaria and universities of southern Africa. Much of this is inaccessible due to the lack of modern data and information management systems. Large organizations with well established databases should develop project-based cooperation with small organizations wishing to computerize their botanical information, assisting them as much as possible with the acquisition of equipment and with training.

A strong need exists for training in the use of computer hardware and software. Regular training courses should be organized at either the National Herbarium in Harare or the National Herbarium in Pretoria.

WORKING GROUP 4
HERBARIUM MANAGEMENT AND NETWORKING

CONVENER: Kevin Balkwill
PARTICIPANTS: Snowy Baijnath, Elise Cloete, A. Dold, Agostinho Duarte, Lyn Fish, Olaf Hedberg, Samira Izidine, Marinda Koekemoer, Patricia Lorber, Gillian Maggs, Alfred Ngwenya

INTRODUCTION

Initial discussions revealed that for herbaria to be of best service for the maintenance of biodiversity, it is crucial that a network for herbaria in the southern African region should be established. Besides this network being essential for cooperative action and provision of information for the maintenance of biodiversity in the region, a training programme would empower the present herbarium staff to perform their functions more competently and productively. It was decided that the Working Group would prepare a motivation that could be used to obtain funding for this network and training programme and in addition, review the essential fields necessary in a computerized herbarium database.

MOTIVATION FOR NETWORK AND TRAINING COURSE

Herbaria and the information they contain are absolutely central to the majority of studies and endeavours on the preservation of biodiversity. The relevant functions of herbaria and information available in herbarium collections include:

- Authentic lists of the records of occurrence of taxa in particular countries and regions.
- Records of distribution.
- Biology of the plant, including flowering and fruiting times.
- Resolution of taxonomic and nomenclatural problems.
- Execution of biological studies, including breeding biology.
- Information about uses of taxa.
- Estimates of abundance.
- Identification of specimens, which facilitates the study of important areas and environmental impact assessment.

In order to optimize the potential of southern African herbaria, the establishment of a network was strongly recommended. The network, which will promote communication and collaboration between herbaria in the region, and its re-inforcement by a training programme, will benefit the members by providing:

- Training for staff, which will facilitate better productivity of the manpower that is presently employed.
- Sharing of ideas and methods.
- Cooperative bulk-buying of herbarium materials to bargain for better prices.
- Limited sponsorship for attendance of meetings.
- Access to addresses of suppliers of equipment and material.
- Access to funding for regional projects.
- Involvement in collaborative regional projects.
- Access to expertise available in other herbaria.
- Access to appropriate arenas in which to share and solve problems.
- Establishment of distribution of taxa in the whole region.
- Steamlining of use of resources; sharing field trips, etc.
- Access to a bartering arena in which duplicate specimens might be bartered for identification services and mounting materials.

The network would furthermore serve the maintenance of biodiversity by establishing a cooperative strategy to serve the needs of the region and reduce duplication of effort. This cooperative strategy would identify centres of excellence in the region, each with emphasis on natural or cultivated taxa; useful, agricultural or scientific applications; local or regional areas; particular types of study and identifications of particular taxa. The network would also initiate joint projects on the collection and collation of herbarium data on priority taxa and areas.

PRESENT FUNDING SITUATION

In an effort to ascertain whether a network and training programme could be funded from the resources presently available in herbaria, the ways in which herbaria generate income were listed. These endeavours include:

- Selling duplicates of specimens.
- Selling plants on Arbor Day.
- Sale of field herbaria of common plants of the area.
- Running of courses for the public.
- Identification charges.
- Consultation fees.

While these methods are quite successfully employed in some herbaria and are very important for linking herbaria to the community, none of the suggestions are sufficiently lucrative for any herbarium to pay its own way in the network. In addition, the following disadvantages and shortcomings were identified:

- All activities are expensive of time and therefore prevent herbarium staff from carrying out the work for which they are actually employed and which will make a more direct contribution to the study and preservation of biodiversity in the region.
- The activities are not appropriate for all herbaria, if they do not have the facilities. The running of courses requires access to teaching facilities like lecture halls and laboratories.
- Many of these activities are not feasible in many communities, as the market is very small.
- The market for duplicate specimens is limited.

As a result, it is necessary to apply to an external body for funding for the network and training programme.

PROPOSED NETWORK STRUCTURE

It is proposed that the network should be the southern African branch of the Network of African Herbaria (NOAH). There will be involvement from neighbouring branches, however. In this regard, provision is made for the involvement of Tanzania as a member of SADC and as a representative of the East African branch, as well as for a single representative from Madagascar and Mauritius. Thus, the participating countries could be:

- Angola, Zimbabwe, Zambia, Botswana, Lesotho, Swaziland, Malawi, Mozambique, Namibia and South Africa.
- The opportunity to participate would be offered to Tanzania and to a single representative for the Mascarene Islands (Madagascar and Mauritius).

The network would operate through annual meetings, the venue for the meeting rotating annually. The secretariat would serve for four years and could be elected at each meeting of AETFAT.

Potential difficulties in communication may arise and must be taken into account in the election of the secretariat and in communication between members of the network.

The Working Group suggested that the following issues be discussed at the first meeting of the network:

- Geographical location of a centre for a computer data network.
- Finalization of structure of training courses and programme.

- Structure of herbarium network and secretariat.
- Sources of funding for cooperative funding.
- Necessity for and recognition of certificates for training course.
- Links to other groups within NOAH.
- Consultation with users on their requirements.
- Common recommended policy for charging for services.
- Guidelines for realistic charges for services.
- Accessioning of minimum data on computers.

TRAINING NEEDS AND APPROACHES

The Working Group recognized the need for training of herbarium staff, for building self-confidence and esteem, for increasing the competence and productivity of staff and for career recognition through the award of certificates of competence. Two proposals were made on the provision of training. Table 4 shows some topics to be covered in training courses for different staffing elements.

TABLE 4.—Checklist of some topics to be covered in training courses

Topic	Researchers and scientists	Collections managers	Technicians
Collecting specimens	***	**	***
Labelling of specimens	***	**	***
Pressing and drying	*	**	***
Mounting	*	**	***
Plant identification	***	***	**
Curation	***	***	*
Herbarium hygiene	**	***	**
Collecting policy	*	***	*
Quality control of data	***	***	*
Access to herbaria for data	*	***	*
Charging for services and information	**	***	—
Contracts for consultation	**	***	—
Computer literacy	***	***	*
Inputting computer data	**	***	**
Public relations	**	***	**
Presentation skills: oral and written	***	***	*
Working with and in the community	***	***	**
Introduction to research	—	***	**
Research productivity	***	***	*
Priority and goal setting	***	***	***
Time management	***	***	***
Personnel management	*	***	*
Self-assertion	***	***	***
Self-esteem	***	***	***

* unimportant; ** important; *** essential.

The first proposal was for a centralized course that would run for up to one month each year. The course would be geared for in-service training. The course may be modular and could therefore only be completed over several years. There would be a structured syllabus with tests, exams and certificates.

Advantages are that the training would be consistent and that methods employed in the major herbaria can be shown *in situ*. The courses would facilitate the development of communication and camaraderie between people from different herbaria in the region. Courses could be tailor-made for people with different ranges of responsibility, e.g. specialist courses for researchers, collections managers and technicians.

The second proposal was for courses run by a trainer who rotated between herbaria. The course would run for up to a month in each country and the trainer would return annually to present another course. The trainer would spend time assessing the needs of a particular herbarium and would then tailor-make a course for that herbarium and its staff.

Advantages are that more people would be trained, the courses would be highly relevant to each herbarium and the needs of its staff complement, the courses could be presented at the appropriate pace and the realities of the particular institution would be taken into account. The biggest advantage is that this would provide a post for someone who would be instrumental in stimulating the field of systematics in the region and who would coordinate the network.

MINIMUM LEVELS OF SPECIMEN DATA NEEDED FOR THE STUDY AND CONSERVATION OF BOTANICAL DIVERSITY

It was accepted that all data available for new specimens that are collected and accessioned into herbaria and computerized management systems, should be entered into the system. A tremendous wealth of data already exists in herbaria, but it is not easily accessible because it has not been computerized. Although the most efficient way of inputting data into a computerized archival system is to input all the data relevant to a particular specimen as it is handled, this would slow down the rate at which specimens can be entered into the system. If only a subset of the data is required to study and preserve botanical diversity, it would be far more effective to enter the subset of information in a first pass and the rest of the data at a later stage.

A decision on a minimum subset of data would facilitate the initiation of a joint project promoting the computerization of collections of all the herbaria in the region. This project would be initiated and promoted by the Network of Southern African Herbaria. It would facilitate:

- The integration of datasets from all institutions in the region.
- The determination of areas of high biodiversity (i.e. the diversity hot-spots of the region).

- The identification of areas with a high priority for further collecting and for conservation.
- The mapping of the distribution of specific taxa.

The fields that were determined as essential by the workshop included:

- The identification of the specimen.
- The locality; this should either be to the level of degrees, minutes and seconds if possible, although it might be more efficient to set up a grid system. For specimens with imprecise information, an indication of the level of error must be provided.
- The collector's name and number, so that the specimen can be uniquely identified and so that duplicates in a number of herbaria can be linked up. In the event that a unique number is not available, the herbarium accession number is substituted.
- The herbarium acronym. This together with the collector's name and number, allows the location of a particular specimen so that unusual localities and flowering times etc. can be double-checked.
- Date of collection, with an indication of phenology. This will allow the determination of flowering and fruiting times.

CONCLUSION

The data needs for botanical diversity conservation would be reviewed by the network of herbaria once established. A questionnaire should be circulated to nature conservation authorities and other scientists working in the field of biodiversity, so that they can comment on the information they would require. It must also be borne in mind at all times that the more data required, the longer it will take to provide them.

WORKING GROUP 5
EDUCATION AND TRAINING

CONVENER: Bruce McKenzie
PARTICIPANTS: Inga Hedberg, Gill Lewis, Barrie Low, Geoff Maneveldt, Nouhou Ndam, Jonathan Spencer Jones, Dan Walmsley, Walter Menne

INTRODUCTION

The relevance of biodiversity in southern Africa needs a drastic shift from its scientific cocoon, into a sphere where its absolute necessity for the sustainability of life on earth is communicated to all people.

This approach must make use of appropriate existing resources through a process which is both efficient and effective. Overall, accessibility to resources as well as education and training programmes must be optimized and should operate across a wide spectrum of target audiences, including primary, secondary and tertiary level teachers, education planners, policy makers and the general public.

FORMAL AND RESEARCH INSTITUTES

The expertise exists in southern Africa to adequately address the teaching, training and research aspects needed for the region. The problems are related to the fact that the expertise and resources (financial and physical) are very unequally distributed across the region. Cooperation and partnerships are essential to address the problems on a regional basis and these need to be addressed by means of commitment to communication programmes such as surveys, forums, workshops, etc. The topic is dealt with at three levels: tertiary, secondary and primary.

1. Tertiary

At the tertiary level, universities, technikons and teachers' training colleges are considered along with the research institutes.

Universities

There is a need, at the undergraduate level, to examine the approaches and syllabi adopted by the various institutions to identify the strengths and weaknesses

in a southern African biodiversity context. Most of the undergraduates at universities will become teachers, and there is a need for communication within universities (i.e. between education and biology departments/faculties) and on the broader 'national' education policy level. Field trips and field experience are aspects that need to be strengthened.

At the postgraduate level, centres of expertise should be identified and others established to cater for the specific requirements of southern Africa. Replication should be avoided on a local basis. A survey would be needed to examine the effectiveness of various postgraduate programmes (e.g. the Masters courses in Conservation Biology offered at the University of Cape Town; the Resource Ecology course at the University of the Witwatersrand and the course offered at the University of Zimbabwe in Tropical Resource Ecology). The state of postgraduate research in taxonomy, plant genetic resources and ethnobotany were areas identified for investigation.

Short courses and forums need to be an important part of postgraduate training in the region. These should involve universities and research institutes and should be spread throughout the region. The quality of science and the notion of excellence should always be of paramount importance in these activities. Field trips and field work were seen as absolutely essential for the training of biodiversity expertise in southern Africa.

Technikons/technical colleges

The relationship and roles of universities, technikons and technical colleges in training and research should be clarified. At present the nature of the roles and philosophies (what is meant by technical training?) are not clear. These institutions should offer professional courses in practical fields and 'technical level' training of taxonomists, conservation diplomas, etc.

Teachers' training colleges

Syllabi and approaches need to be addressed and professional biologists need to be consulted on these issues. Field trips and field experience should form a major component of the courses.

2. Secondary and primary

The standard 8, 9 and 10 textbooks and therefore the standard 8, 9 and 10 syllabi concentrate mainly on plant anatomy and physiology, with smaller sections on systematics, genetics and ecology. Plant diversity and conservation are lacking at this level and taxonomy is not mentioned. African examples are used, but not extensively.

Very simple textbooks are available at primary school level for the general science course. Emphasis is given to weeds and food plants (crops) and less attention to the wealth of indigenous plants and their uses in southern Africa.

Children at standard 6 and 7 levels should be introduced to ecology, conservation and biodiversity through field experience and visits to botanical gardens, museums and herbaria where available. Fieldwork does not have to be complicated or costly—a walk around the village or into the bush may be all that is needed. The syllabus at this level should be flexible to give teachers the chance to concentrate on local environmental issues. The syllabus for standards 8, 9 and 10 should be gradually overhauled to reflect more African and modern approaches.

At primary school levels, children should be encouraged to take an interest in wild plants, their uses and conservation on a simple level.

Communication and liaison between government departments of education (who write the syllabus), teachers and teachers' training institutions should be improved. The use of existing environmental education facilities (e.g. environmental education centres, programmes, staff and resources) should also be improved.

An overhaul of the school syllabus at all levels by a working group comprising members from the government department concerned, teachers, teachers' training colleges, university education and botany departments as well as environmental education practitioners, should be undertaken as soon as possible.

In-service training of teachers on issues such as conservation, field work and modern methodology is necessary.

ANCILLARY SERVICES AND RESOURCES

Resources such as botanical gardens, herbaria, nurseries and nature reserves should be suitably developed to contribute to public education. They should be interesting and informative and should therefore offer appropriate multimedia information on the resource and its importance.

Botanical gardens should serve education by means of garden areas with special themes, and by focusing on the relevance of plants to our survival, for example:

- Traditional use of plants (food, medicinal, crafts, etc.).
- Indigenous gardens (links with environment), will help people to green their area.
- Education centre for teachers and pupils.
- Displays of ecosystems of the region.
- *Ex situ* conservation of endangered species.

A southern African network of botanical gardens has to be established, perhaps as a regional group within Botanic Gardens Conservation International (BGCI).

Small nature reserves in or near urban areas should be used to demonstrate human impacts on biodiversity.

NONGOVERNMENTAL ORGANIZATIONS (NGOs)

Informal education has a crucial role to play in creating an awareness and interest in botany as a subject, as a hobby and as a career, and in the study of biodiversity as fundamental to the sustainability of life. Volunteers and professionals from nongovernmental organizations should be harnessed to assist in this process.

Personnel attached to NGOs can be used for activities such as marketing plants and trails, acting as guides, preparing resource materials and fundraising. Such activities require coordination to be effective.

CONCLUSIONS

The Working Group recommended that a Task Group, within a network of southern African botanists, be established to:

- Investigate undergraduate training in southern African universities.
- Conduct a survey of postgraduate botanical expertise in southern Africa.
- Collate the type of information and approach appropriate to school syllabi and communicate this to the relevant policy authorities.
- Investigate the status of botanical gardens in southern Africa.
- Address media and perform the public relations task needed to promote botany and the conservation of botanical diversity.

WORKING GROUP 6
SPECIES-LEVEL ISSUES AND ACTIONS

CONVENER: Craig Hilton-Taylor
PARTICIPANTS: Liz Ashton, Aleka Beaumont, Mandy Balkwill, Wayne Boyd, John Burrows, Sandy Burrows, John Donaldson, Anthony Hall, Geoff Nichols, Rob Scott-Shaw, Stella Simiyu, Raida Stanvliet, Wendy Strahm

INTRODUCTION

Species-based issues and actions entail the review of taxa with the aim of identifying species considered to be of high priority for conservation attention, particularly threatened species and species of actual or potential resource value. Conservation plans can then be developed for these species, often using a combination of *in situ* and *ex situ* measures. This approach is epitomized both nationally and internationally by the compilation and publication of *Red data books* which examine the status and conservation requirements of threatened species in detail. The present and future role of *Red data books* in southern Africa was discussed by this Working Group.

For the purposes of this report we have referred to the southern African subcontinent as southern Africa. Regions are regarded as units which are likely to have independent approaches to the conservation of species in a particular area, i.e. this category could include entire countries or political units (e.g. provinces) within a country. Countries are sometimes referred to as such. 'Local' refers to a geographical portion of a region.

ARE *RED DATA BOOKS* NECESSARY?

It was agreed in principle that *Red data books* (RDBs) were necessary because they:

- Record the conservation status of taxa at a particular point in time and are therefore useful in monitoring changes in biodiversity over time.
- Establish the nature and extent of rarity and/or decline.
- Stimulate management and research actions on endangered species by giving them a higher profile.

- Highlight taxonomically poorly known groups, thereby helping to raise the quality of systematics in southern Africa.
- Are useful tools in helping to identify and manage southern Africa's biodiversity.

Despite their utility, it was recognized that RDBs had disadvantages and limitations:

- Given existing knowledge and resources, only a small proportion of southern Africa's rich flora can be adequately surveyed to set priorities.
- Not all species are equal, and existing RDBs have failed to provide a suitable framework for prioritization.
- Resources to implement conservation action or recovery plans are available for only a small proportion of the taxa identified as being of high priority.
- Allocation of extensive resources to the conservation of a small number of high-profile or priority species may not be the most efficient use of the scarce resources, especially if the conservation measures involve a large amount of *ex situ* management, as this does not benefit any other species.
- The rare and endangered species of today are not necessarily those of the future; common species may be at risk due to global climatic changes.
- RDBs fail to answer questions at the ecosystem and landscape levels.

The ecosystem-level and species-level approaches were seen as being complementary activities. These two approaches could be reconciled by the identification of areas of high diversity and endemism ('hot-spots'), and by using particular threatened species as 'flagships' to justify the preservation of portions of the ecosystem or habitat, thereby conserving other species of lower conservation profile.

The format of RDBs should be changed to meet the requirements of different user groups, e.g. conservation managers, developers, politicians, amateur botanists, traditional users and biologists, thereby extending their utility.

The conventional RDB takes too long to generate. A format that can be updated more frequently would be more appropriate. In addition a simple inventory of threatened plants may be more appropriate for some countries in southern Africa. Ideally, all threatened plant data should be computerized to enable the output of information at whatever frequency and in whatever format desired. This would also enable one to track a species over time.

While RDB inventories are most useful at a local or regional level (e.g. provincial) where many of the threats to specific plant species are operative, they also serve an important function at the country or southern African level. The prime

value of such inventories for southern Africa would be to eliminate areas of overlap between countries and regions, to identify priority areas or species within southern Africa, thus ensuring coordination across the region and also presenting a coordinated overview when lobbying for funds and resources.

WHAT FORMAT SHOULD *RED DATA BOOK* INVENTORIES TAKE?

Regional databases containing information on threatened plants should be established. From these databases, lists or inventories should be produced regularly (every 2–3 years) at a local and/or regional level. These lists would only be approximations as they would be a reflection of the state of knowledge on the flora of the area at that time.

Overall summaries at a national level and for the whole of southern Africa should be compiled and published at longer intervals (about every 5 years). This information would be produced from a national database established and regularly updated from summary data provided by the regional databases.

There should be a minimum set of information included in inventories which would facilitate more frequent publication. This minimum set would be established after consultation with all the producers and all the potential users. Additional information could be added as and when appropriate. The minimum information should be the following:

- The currently accepted name of the taxon, including author/s.
- The threatened status of the taxon at both the local/regional level and at the southern African level (i.e. global level) using either the proposed IUCN threatened categories, if accepted (Mace *et al.* 1993), or the present IUCN categories in conjunction with another system (e.g. Rabinowitz 1981) which takes into account abundance, distribution range, habitat specificity, etc. This approach would ensure the inclusion of taxa which, although not threatened throughout their range, are of local/regional conservation interest. If the new categories are accepted, the criteria used for allocating the status will have to be specified.
- The distribution of the taxon, not only within the area of concern, but if possible its entire known distribution range.

Additional information would include:

- A brief description of the taxon with diagnostic features, growth form, phenology and other relevant taxonomic information (e.g. recent synonyms and taxonomic uniqueness).
- Information on the biology of the species (e.g. habitat requirements, pollinators, dispersers and propagation requirements).
- Identification of threats and prioritization for conservation action.

- Advice on monitoring.
- References to the pertinent literature.

MAJOR GAPS

Much of the southern African flora has not been re-evaluated since 1980 and there are certain geographical areas with very little or no information on threatened species.

- Table 5 summarizes the *Red data books* or lists that have been published and other threatened plant information that is available for all the countries in southern Africa.
- Apart from the general studies mentioned before, there have also been a number of detailed accounts looking at threatened species within certain plant groups (e.g. Tansley (1988) and Pool *et al.* (1992) on

TABLE 5.—*Red data books* and lists available for southern Africa

Region	*Red data book*	Coverage
Southern Africa	Hall *et al.* (1980)	All countries in the *Flora of southern Africa* region
Angola	No RDB; only limited information from WCMC*	
Botswana	No RDB since Hall *et al.* (1980); limited information from WCMC	
Lesotho	No RDB since Hall *et al.* (1980); limited information from WCMC	
Mozambique	No RDB; only limited information from WCMC	
Malawi	No RDB; only limited information from WCMC	
Namibia	No RDB since Hall *et al.* (1980); limited information from WCMC; Hilton-Taylor (in prep.)	Lüderitz and Warmbad districts
South Africa		
Cape Province	Hall & Veldhuis (1985) Everard (1988) Hilton-Taylor (in prep.) Anderson (unpublished)	Fynbos and Karoo Eastern Cape Succulent & Nama-Karoo Northern Cape
Natal	Scott-Shaw (unpublished)	
Orange Free State	Not evaluated since Hall *et al.* (1980)	
Transvaal	Fourie (1988); Boyd (in prep.)	
Bophuthatswana, Ciskei, Transkei and Venda	Not evaluated since Hall *et al.* (1980)	
Swaziland	Braun (unpublished)	
Zambia	No RDB; only limited information from WCMC	
Zimbabwe	No RDB; only limited information from WCMC; some literature on specially protected plants, particularly the succulent species	

* WCMC = Threatened Plants Unit of the World Conservation Monitoring Centre in Cambridge, England.

Cape Proteaceae; Fourie (1984) on Transvaal Euphorbiaceae), and intensive autecological studies on certain species (e.g. Boucher (1981) on *Orothamnus zeyheri*; De Lange's (1993) series of papers on *Audouinia capitata* in *South African Journal of Botany* 59). Many more studies like these are required to gain a greater understanding of our endangered species.

The direct involvement of professional taxonomists and herbaria is required in the following tasks:

- Clarifying the taxonomy of poorly known groups.
- Aiding in the process of identifying threatened plants.
- Providing essential information on the distribution and biology of threatened taxa, e.g. phenological data and growth forms.
- Identifying undercollected areas and organizing collecting trips to these areas (e.g. the trips arranged under the auspices of the Plant Systematics Stimulation Group).
- Indicating the conservation status of taxa in monographs or flora treatments.

The Working Group recognized the need for some kind of prioritization within threatened categories, e.g. priority being given to taxa threatened by impending development, or to taxonomically unique taxa (Given & Norton 1993; Hall 1993).

There is a poor understanding of natural rarity in plants (Fiedler & Jain 1992; Kunin & Gaston 1993).

There is a major lack of communication at various levels:

- Between producers of RDBs and people with relevant information to contribute (e.g. taxonomists and keen amateurs).
- Between compilers of RDBs and potential users (who audits RDBs?).
- Between the compilers of RDBs for different regions, resulting in a certain degree of overlap and duplication of efforts.

Monitoring of trade in threatened species is a major gap:

- Apart from the work done by TRAFFIC on CITES-listed taxa, there is very little monitoring of trade in threatened species and no monitoring of commercial trade in species not thought to be threatened (this excludes medicinal plants).
- There is little uniformity between and within countries in southern Africa in the implementation and enforcement of CITES legislation.
- Greater cooperation on trade and conservation legislation matters is required between governmental conservation agencies and also be-

tween these agencies and the various nongovernmental organizations (NGOs).

There is no coordinated structure to address the gaps identified above and to provide some level of cooperation.

HOW TO GET THERE—STRATEGIES AND ACTION PLANS

1. Regional coordination

As a result of this workshop we have identified contributors of plant species information and recognize the need for a forum for the exchange of information and ideas. Some existing groups that could contribute to this forum include universities, conservation bodies (governmental and NGOs), herbaria, independent researchers, amateur botanists and traditional users. We recognize the need for networking between these groups, both regionally and internationally. We also recognize the need to provide the means whereby amateur botanists and users can feed into the system.

We foresee the establishment of a Southern African Threatened Plant Specialist Group, possibly under the auspices of the IUCN Species Survival Commission. This workshop has provided the springboard for such a group. However, we feel that without a full-time coordinator the group will be unable to operate effectively. The coordinator would also require the infrastructural support of an established botanical institution and a budget to cover operating costs.

The first step in implementing this strategy would be the appointment of the coordinator who would invite plant specialists to participate in the group. The group would be open to all plant specialists with knowledge on the southern African flora. The development of regional groups should then follow.

The first task of the Southern African Threatened Plant Specialist Group would be the development of an action plan highlighting plant conservation priorities for southern Africa.

The task of the coordinator would be:

- To collate and publish a regular newsletter.
- To obtain funds and to ensure that working groups are established to tackle specific issues.
- To initiate and help establish local/regional working groups and to establish linkages between the groups so as to avoid overlaps and duplication of efforts. These working groups should include all the relevant experts for the area and each group should appoint a coordinator/chairperson. These groups should develop computerized databases containing detailed information on all the threatened

species that occur within their area. These databases should also be linked to other botanical/environmental databases, preferably within an effective geographic information systems (GIS) framework. Protocols concerning the disclosure of information, data security, and ownership of the data will have to be established.

- To develop public awareness on threatened plants. This would be done in conjunction with the local/regional coordinators.
- To establish international links with similar organizations such as the Center for Plant Conservation, based at Missouri Botanical Garden in the USA, and the Australian Network for Plant Conservation under the auspices of the Australian National Botanic Gardens.

Meetings of the specialist group could coincide with international and local botanical gatherings (e.g. the annual meetings of the South African Association of Botanists, AETFAT meetings).

In summary, the following action is required as a first priority:

- Establish a network of individuals and organizations working on threatened plants in southern Africa.
- Appoint a southern African coordinator.
- Establish the Southern African Threatened Plant Specialist Group.
- Initiate local/regional working groups.
- Produce an updated list of threatened plants for southern Africa using currently available data.

2. Basic assessments and monitoring

A coordinator should be appointed for each region, whose duties will be to facilitate and coordinate the assessment and monitoring of threatened plant species in the region (within the limitations of resources) and to formulate action plans based on assessment and monitoring data. The regional coordinator will report to the coordinator for southern Africa and will automatically be a member of the Southern African Threatened Plant Specialist Group.

Data accumulated during assessment and monitoring should be collated by the regional coordinator and distributed to relevant local interest groups as well as to the national coordinators and/or to the coordinator for southern Africa. These data should be exchanged free-of-charge. However, if the information is to be used for commercial gain, a charge may be levied. (Note: no data will be given out by the southern African coordinator without the prior approval of the regions who provided the data.) Feedback will also be given to managers to ensure their cooperation in conservation efforts and relevant data will also be passed on to policy makers and planners.

Assessments should be the responsibility of regional or local authorities who should encourage the participation of local interest groups (e.g. amateurs in NGOs such as the Botanical Society and Succulent Society) or individuals (e.g. non-professional botanists, landowners and farmers) where this will not be detrimental to the species being assessed (as might be the case with cycads). The use of volunteers is especially important for those regions with a chronic shortage of trained staff.

Assessments should first be at the level of basic inventory type surveys, followed by more sophisticated analyses of populations where the skills and resources are available.

The Southern African Threatened Plant Specialist Group should provide guidelines for evaluating the status of plant taxa in different regions so that it is possible to collate and compare data from different regions.

Guidelines should be set out for the monitoring of threatened plant taxa. These guidelines must include techniques for deciding which taxa should be monitored, how and when they should be monitored, how frequently, and at what level populations should be monitored.

REINTRODUCTIONS AND TRANSLOCATIONS

Reintroductions or translocations must be extremely carefully considered as a last-resort action and must be carried out under the advice of experienced and trained personnel.

Translocations should be carried out only after an assessment of the reasons for the decline of the species and after consideration of reintroduction as a better alternative.

The success of reintroductions and translocations should be monitored and successes and failures should be documented (Maunder 1992). The success of reintroductions carried out so far in southern Africa should be analysed to determine whether the effort is warranted or whether other conservation measures are necessary. Attempts should also be made to identify the ecological and horticultural factors affecting the success or failure of reintroductions.

Reintroduction case histories should be widely publicized to generate interest and support and to guide future initiatives.

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WORKING GROUP 7

ECOSYSTEM-LEVEL ISSUES AND ACTIONS

CONVENER: Tony Rebelo
PARTICIPANTS: Hugo Bezuidenhout, Sizwe Cawe, Fernando Costa, Annelise le Roux, Mahlape Mothepu, Nouhou Ndam, Jonathan Timberlake, Julia Wood

DESIGNING A CONSERVATION NETWORK FOR PRESERVING ECOSYSTEM AND PLANT BIODIVERSITY IN SOUTHERN AFRICA

INTRODUCTION

Conservation in southern Africa has happened haphazardly, centered on the need to conserve specific threatened mammals. Although plant species and vegetation types have recently become more important in assessing the efficiency of conservation systems, they have seldom featured in the motivation and management of conservation areas.

Southern Africa is one of the most diverse of the botanical regions of the world. With 22 000 plant species interacting with thousands of animal species and a wide variety of geological substrates, landscapes and a long history of climate changes, an efficient conservation strategy is required for efficient conservation. As a minimum goal we need to identify a regional (subcontinental) network of potential conservation areas by the year 2000. Even then, certain systems will have been transformed and degraded beyond rescue.

Such a network must adequately include a representative, functional sample of the ecosystems and species diversity in southern Africa. These need not all be strict, traditional 'reserves' and 'parks', but must range from exclusive conservation/wilderness areas to multiple-use areas, based on the limits imposed by the conservation requirements of the system. Thus clear-felling may be compatible with some grassland conservation, but not with forest conservation. Implicit in this outlook is that the designated areas must be capable of sustaining their objectives in the long term. At the same time they must be acceptable to the local community: there is a growing resistance to off-limit lands which yield no benefits to local communities.

The overall conservation system must be assessed periodically at national and subcontinental levels to evaluate its effectiveness. At the same time the

system must include redundancy and flexibility so as to allow for unforeseen disasters, lack of knowledge concerning system processes and changing pressures, including habitat destruction and climatic change. In this regard alternative back-up and fall-back sites must be identified.

WHERE ARE WE NOW?

At this stage we do not have a subcontinental perspective on what is known. Regionally data are available, but in specific areas information is lacking. The major problem is in obtaining and collating this information. We do not even have a uniform map of vegetation types within the subcontinent at scales appropriate to planning, although such maps exist for most countries.

There is need to coordinate and manage ecosystem-level research for conservation. Generally, such research happens as a conservation management need is identified. What is required, is an overall conservation plan and an effective action plan to ensure ecosystem conservation at a subcontinental level.

Existing conservation areas

All countries have areas that are protected, generally covering quite large areas, but this network of reserves has been established on the basis of large-mammal conservation needs, mountain catchment conservation and to a lesser extent forest resources. These areas were designated *ad hoc* and not primarily for protecting biodiversity. As a consequence, the reserve network is probably inadequate for protecting representative botanical diversity, including ecosystem processes.

The status of protection and efficiency of specific reserves is in general well known, but considerable discrepancies exist between countries. The potential for existing reserves to meet their original goals is poorly known in Angola and Mozambique and varies with changing political conditions.

We do not know which plant species occur in each reserve and which of these are adequately protected. In most cases we are not sure which animal species may be essential for their efficient conservation. At a broader scale, the proportions of major vegetation types in conservation areas are known, or can be calculated. However, in some countries such data for evaluating the effectiveness of these reserves do not exist, or have been lost, or are simply not easily obtainable at a national or international level.

Species data

It is impossible to separate species from ecosystem phenomena: keystone species control ecosystem processes; flagship species allow for the conservation of ecosystems; indicator species allow the monitoring of ecosystem processes;

pest species interfere with 'natural' ecosystem processes. Management is usually geared towards benefiting a specific species rather than an ecosystem process.

Plant distributional data are not nearly as comprehensive as data for birds and mammals. However, such data are essential for conservation planning. Species are the fundamental units of measuring, delimiting and monitoring vegetation types and ecosystems. Without comprehensive species data, effective planning and monitoring cannot be undertaken. Three aspects are required: a good taxonomy, good distributional data and information on the conservation status of each species.

There are biases in taxonomy. Some groups are particularly poorly understood (e.g. Mesembryanthemaceae, Alliaceae) so that assessing their conservation status is impossible. With these exceptions, there are no major gaps or problems in taxonomy from an ecosystem/vegetation-type perspective, although, with the exception of trees and grasses, very few plant families are extremely well studied on the subcontinent. The flora of Angola is particularly poorly known.

Locality data exist in herbaria, but these are generally not accessible for biogeographical analysis. Where such data are available, they are limited to grid squares of about 25 × 25 km. Conservation assessment requires that localities be known at the spacial level of farms or nature reserves, but such data are not computerized at an adequate scale. By contrast, vegetation-type surveys have detailed point locality data, but such studies are not available for all southern African countries. Where they exist, the data are usually presented in a highly summarized form, often without adequate voucher specimens, and often with the original data lost or in an unsuitable form.

Status of species and populations with regard to conservation, threats, rarity and long-term survival (such as regeneration requirements, recruitment, etc.) is generally poorly known, except for some focal and locally rare species.

In general, herbaria, atlas projects and vegetation surveys are the major sources of species-level data required for conservation planning.

Ecosystem process data

Very little is known about ecosystem processes at the local level. At a subcontinental level, vegetation, landscape, geology and soil types probably reflect ecosystem processes. However, the scale at which essential processes operate is generally unknown. For instance, is 10 per cent of a vegetation type adequate for its preservation? Can this equally be achieved in *n* areas of 10/*n* per cent?

In general, knowledge of ecosystem processes is available for conservation at a regional scale, although for smaller areas and local nature reserves this knowledge may not be adequate. Where data are not available, current data can probably be readily obtained from satellite imagery.

In reality, many necessary data required are site-dependent, and cannot easily be determined from broad scale studies. Thus the position of a reserve on a river may determine the impact of water extraction on riparian systems. This may or may not have a marked effect on non-riparian systems in the reserve.

Existing legislation

In designing a conservation system for the subcontinent, it is essential that the existing legislation needs to be gathered and synthesized, as it is within the framework of the existing legislation that conservation areas will have to be apportioned and the system designed. The legislation will have to be periodically reviewed to assess its efficiency and loopholes, and to canvas for changes in legislation when it is found to be inefficient.

Processing facilities

On a subcontinental basis, the use of computer technology in conservation planning is well advanced. Even high-tech data analysis using GIS can be done at many centres in South Africa and at Harare, Gaborone and Maputo. However, problems exist locally. The major subcontinental problem is one of inadequate local expertise and the need for the field validation of units determined by remote sensing.

WHERE DO WE WANT TO BE? WHAT IS REQUIRED?

The Working Group identified the following priority needs:

- Collection, collation, analysis, publication and review of available plant distributional data on GIS and databases.
- Identification of key people and institutions for carrying out the collection, analysis and review: the establishment of a task force.
- A computerized ecosystem map of the subcontinent.
- The computerization of herbaria, preferably with site-based rather than grid-based locality data.
- The coordination and collation of atlas projects and the publication of available data.
- Evaluation of the capacity to fill gaps in data and maps. Where the capacity does not exist, capacity building at the national level should be supported.
- The results of findings need to be taken to national bodies concerned for implementation.

- International financial assistance will be required, both for planning the conservation system and for education and remuneration of local expertise.
- It is strongly felt, however, that the subcontinent must determine its own requirements and implementation programmes, and not be dictated to by funding agencies.
- There is a need to ensure that institutions are able and willing to manage and monitor the conservation areas under their jurisdiction and make necessary adjustments to ensure that they achieve their stated goals.
- There is a need to ensure that a periodic regional review of the objectives and goals is performed based on additional data.

HOW TO GET THERE: AN ACTION PLAN

- Identify a focal person for initiating the action plan. This will have to be a political figure who understands botany and botanists.
- Funds must be obtained to run the task force. The IUCN is probably the body that would get acceptance from all southern African countries. A coordinator should be from within the region (or familiar with the politics and conservation needs of the region).
- The next step is to set up a task force comprising representatives from each country in the subcontinent.
- The task force must collect, collate, and review information on both a local and subcontinental scale.
- The task force must then identify gaps in the data and assess the feasibility and responsibility of filling in the gaps.
- The task force should ensure that the necessary projects are designed, funded, implemented and reviewed, through appropriate local channels, for the short-term collecting of data in the identified gaps. This must involve local botanists and allow for their further education in order to carry out these tasks.
- The task force must liaise its findings with national bodies, offering adequate explanation, ensuring acceptance, and guiding implementation and monitoring. Alternative conservation options should be borne in mind. Education and training may be required locally to implement these actions.
- The task force should produce various reports and guidelines to both the local policy makers and the international community, including:
    - A first assessment of the current conservation system. This should identify the major gaps in data and in the conservation network on

the subcontinent and set the framework for future research and conservation actions.

- A proposed network of conservation areas including options for back-up and details of subcontinental-level requirements, including monitoring requirements.
- Identifying areas is not enough: the objectives, management and monitoring requirements for each reserve within the system must also be determined in terms of ecosystems, species and processes which must be maintained. Subcontinental and local priorities must be resolved with national and regional conservation agencies. Areas of social conflict must be identified and structures set up to resolve such conflicts and oversee local implementation.
- A proposed implementation strategy, including time tables, costs and alternatives. The details and power of the task force will depend to a large degree on its ambit and social acceptance both subcontinentally and internationally.
- Other outputs envisaged include:
    - A GIS-generated map of subcontinental vegetation types, ecosystems, conservation areas and species distributional data.
    - An ecosystem map derived from LANDSAT and existing maps.
    - Documentation on the status, effectiveness and other inputs pertaining to existing conservation areas and phytodiversity of the subcontinent.
    - A compendium of which data are available in terms of species lists, vegetation surveys, and where and in what form they are available.

    The task force should be given a time limit of 10 years to achieve its goals, thereafter serving mainly as a watchdog assessing political and climatic changes and their implications to the conservation network.

WORKING GROUP 8
INTERNATIONAL CONVENTIONS

CONVENER: Steven Njuguna
PARTICIPANTS: Kate Braun, Augustine Chikuni, Agostinho Duarte, Cornelia Erasmus, Liz Matos, Walter Menne, Nouhou Ndam

INTRODUCTION

Biodiversity conservation seeks to maintain the human support system provided by nature, and the living resources essential for development. It entails a shift from a merely defensive posture—protecting nature from the impacts of developments—to an proactive effort seeking to meet people's needs from biological resources while ensuring the long-term sustainability of the earth's biotic wealth.

The importance of conserving biodiversity was one of the main issues addressed at the Rio Earth Summit in June 1992. Negotiations for a Convention on Biological Diversity began in November 1990 under the auspices of the United Nations Environmental Programme (UNEP). The text was adopted in Nairobi in May 1992 and opened for signature at the Earth Summit in Rio de Janeiro in June 1992.

WHERE ARE WE NOW?

International Conventions and Action Programmes that may have an effect upon the conservation biodiversity are outlined here:

The Convention on Biological Diversity

Background

The Framework Convention on Biological Diversity was agreed to on 23 May 1992 after nearly four years of negotiations under the auspices of UNEP. In June of the same year it was presented to the UN Conference on Environment and Development (the Earth Summit) in Rio de Janeiro for signature by governments.

Main activities and purpose

The Convention provides a framework for the conservation of the biological diversity of the planet and the sustainable use of biological resources. The objectives of the Convention are:

- The conservation of biological diversity.
- The sustainable use of biological resources.
- The fair and equitable sharing of benefits from the use of genetic resources.

The key implementation measure of the Convention is the development of national biological diversity conservation strategies by all countries, coupled with attempts, mainly on the part of developed countries, to provide funds, technology and related assistance to developing countries for conservation actions identified in the strategies.

Secretariat

Address: Interim Secretariat, 15 Chemin des Anémones, CH-1219 Châtelaine, Geneva, Switzerland.

Entry into force

The Convention entered into force at the end of 1993.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Background

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was adopted in Washington on 3 March 1973, as a result of an Intergovernmental Conference on Endangered Species, and entered into force on 1 July 1975.

Main activities and purpose

The objectives of this Convention are to protect certain endangered species from overexploitation, by means of a system of import/export permits. The Convention is open for accession to all states.

Secretariat

The CITES Secretariat in Lausanne, Switzerland, services the network of national authorities and the meetings of the Conference of the parties, assists in trade monitoring and compliance control and coordinates related studies and

information exchange. Address: 6, rue du Maupas, Case Postale 78, CH-1000, Lausanne 9, Switzerland.

Parties to the Convention

On 6 January 1993, there were 117 parties to CITES, covering almost the entire world.

The Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat

Background

The Ramsar Convention provides the framework for international cooperation for the conservation of wetland habitats. Although the text was adopted in 1971, the Ramsar Convention entered into force late in 1975 and now has contracting parties from regions throughout the world.

Main activities and purpose

Under the Convention, governments undertake to respect four main obligations:

- To designate at least one wetland for inclusion in the List of Wetlands of International Importance.
- To promote the wise use of wetlands.
- To consult with each other about implementing the obligations arising from the Convention, especially, but not exclusively, in the case of a shared wetland or water system.
- To create wetland reserves.

Any member state of the United Nations, one of its specialized agencies, the International Atomic Energy Agency (IAEA), or a party to the Statutes of the International Court of Justice may become a party to the Convention.

Secretariat

The Secretariat, or Bureau as it is known, is an independent body administered by the World Conservation Union (IUCN). Its headquarters are located at Gland, Switzerland. The Bureau services an international network and the meetings of the contracting parties and its committees. Address: Ramsar Convention Bureau, Avenue du Mont-Blanc, CH-1196, Gland, Switzerland.

Parties to the Convention

On November 1993, 80 countries were party to the Ramsar Convention.

Convention Concerning the Protection of the World Cultural and Natural Heritage

Background

The Convention Concerning the Protection of the World Cultural and Natural Heritage, better known as the World Heritage Convention, was adopted by the Governing Council of the United Nations Economic and Social Council in 1972.

Main activities and purpose

The primary function is to define the worldwide natural and cultural heritage and to draw up a list of sites and monuments considered to be of such exceptional interest and such universal value that their protection is the responsibility of all humanity.

Secretariat

Address: World Heritage Secretariat, Division Ecological Sciences, UNESCO, 7 Place de Fontenoy, 75700 Paris, France.

International Undertaking on Plant Genetic Resources

History

The International Undertaking on Plant Genetic Resources was established by Resolution 8/83 at the Twenty-second Session of the Food and Agriculture Organization (FAO).

Main activities and purpose

The objective of this undertaking is to ensure that the plant genetic resources of economic and/or social interest particularly for agriculture, will be explored, preserved, evaluated and made available for plant breeding and scientific purposes. This undertaking is based on a universally accepted principle that plant genetic resources are a heritage of all humanity and consequently should be available without restriction.

Secretariat

Address: The Secretary General, International Undertaking on Plant Genetic Resources, FAO, Viale delle terme di Caracalla, 00100 Rome, Italy.

African Convention on the Conservation of Nature and Natural Resources

History

This Convention was adopted at Algiers on 15 September 1968 and entered into force during June 1969.

Main activities and purpose

To encourage individual and joint action for the conservation, utilization and development of soil, water, flora and fauna for the present and future welfare of humanity, from an economic, nutritional, scientific, educational, cultural and aesthetic point of view.

The fundamental principle, binding on all contracting states, is to ‘undertake to adopt measures necessary to ensure conservation, utilization and development of soil, water, floral and faunal resources in accordance with scientific principles and with due regard to the best interest of the people.’

Secretariat

The Organization of African Unity (OAU) is the depository body for Instruments of Accession.

Parties to the Convention (southern Africa)

Malawi, Mozambique, Swaziland, Tanzania, Zambia.

The Framework Convention on Desertification

The Framework Convention on Desertificaton is currently in the process of being negotiated. This Convention will be of importance to all African countries.

WHERE DO WE WANT TO BE?

The level of adherence to the various Conventions within southern Africa is indicated in Table 6. Countries of the region want to be regarded as in step with the rest of the world: caring about the conservation of nature, natural resources and biological diversity. Countries should strive to join, where applicable, all relevant Conventions. Benefits to be derived from membership of International Conventions include:

- A large pool of knowledge and expertise in which parties can share.
- Financial assistance (GEF, Wetland Conservation Fund).
- Help in conflict resolution, regionally and internationally.
- Safeguarding of property rights.

TABLE 6.—Current status of southern African countries with regard to some important International Conventions

	Biological Diversity	CITES	Ramsar	World Heritage	International Undertaking on Plant Genetic Resources
Angola	S	X	X	R	X
Botswana	S	P	X	X	–
Lesotho	S	P	X	X	X
Malawi	S	P	X	R	A
Mozambique	S	P	X	R	A
Namibia	S	P	X	X	X
South Africa	S	P	P	X	A
Swaziland	S	X	X	X	X
Zambia	R	P	P	R	A
Zimbabwe	S	P	X	R	Res A

A = adhere to Understanding/Convention; P = party to Convention (either by ratification or accession); R = ratified; Res = reservation; S = signatory; X = nonparty to Convention.

- Unified approach which can enhance regional cooperation.
- Contribution to Convention restructuring.

WHAT SHOULD WE DO TO GET THERE?

Relevant government agencies and NGOs should go out of their way to acquire and disseminate information to interested and affected parties regarding International Conventions/Regional Agreements/Action Programmes. Pressure should be exerted by technical departments and interested parties on governments in this regard, should it be necessary. A forum or liaison body should be established between NGOs and government departments to discuss matters pertaining to Conventions: new developments, obligations, action plans, etc. This body could be affiliated with Science and Technology Councils.

It would be useful to establish regional forums to discuss Convention matters. These regional forums would be Convention-specific to ensure maximum focus on the objectives of the Convention. The need exists for a layman's version of Convention texts explaining all obligations and benefits of being party to a Convention in an easy-to-understand language. The layman's version would emphasize benefits, negative consequences of not signing and would have information on obligations and commitments. At national level, there is a need to establish and update a database on Conventions in terms of status, signing, ratification and obligations, and to initiate national forums to collaborate with legal departments on Convention matters.

WORKING GROUP 9

PROTOCOL FOR A PLANT GENETIC RESOURCES PROGRAMME

CONVENER: Helen Moss
PARTICIPANTS: Matt Erasmus, Mariaan Jooste, Henry Kamau, At Kruger, Liz Matos, Paulino Munisse

INTRODUCTION

Plant genetic resources are defined as the assemblage of plant germ plasm which contains useful characters of actual or potential value.

South Africa is in a somewhat anomalous position within the southern African region because, as yet, no formal national plant genetic resources programme has been established. This is largely due to the fact that the conservation and utilization of genetic resources is a branch of science which developed into a recognized discipline only during the decades when South Africa was isolated from most of the rest of the world. During the latter part of this period, national plant genetic resources programmes were established in many countries of the world, particularly within developing countries.

In contrast to the situation in South Africa, the ten other countries of the region are affiliated within the SADC Regional Genebank (SRGB), which is based just outside Lusaka. SRGB, together with the International Board for Plant Genetic Resources (IBPGR), has assisted each of the member states to establish a national plant genetic resources programme, each of which functions as an integral component of the regional programme. This initiative has strong ties with major international genetic resources activities. Thus, contrary to the situation which exists in most of the other botanical disciplines in southern Africa, there is an already established and functional regional Plant Genetic Resources (PGR) initiative with strong national components. For this reason, the action plan outlined here is focused largely on establishing a parallel programme in South Africa. It should then be relatively easy to incorporate this initiative into the regional programme once South Africa becomes a member of SADC.

WHERE WE WANT TO BE—AIMS AND OBJECTIVES

Long-term goal

The ultimate long-term goal of a genetic resources programme is to conserve and maintain in gene banks, botanical gardens, nature reserves and arboreta, using *ex situ* or *in situ* collections as appropriate, the maximum genetic and species diversity of plants. Ideally this would be done on a regional co-operative basis, in order to conserve and utilize this resource of scientific, strategic and economic value for the benefit of the people of the region.

Short- to medium-term goal

Fundamental to the attainment of this goal will be the establishment of an effective plant genetic resources programme at a national level, with strong regional and international links. On the national level it will have to be closely affiliated with and integrated into other biodiversity and related programmes such as those in agriculture, forestry, ethnobotany and horticulture. Apart from other considerations, this would allow a substantial part of the day-to-day work of the programme to be carried out by existing institutions, rather than necessitate the establishment of an entirely separate body. With strong coordination, this scenario ought to be realistic.

THE CURRENT SITUATION

South Africa was, until 1994, isolated from the international and regional genetic resources community as a consequence of its political policies. Because of the international nature of the most significant genetic resources initiatives and the mutual interdependence of all countries on this resource, this situation accounts for the country lacking a coordinated national programme in this field.

South Africa's previous isolation, together with the country's almost complete dependence on a supply of imported germ plasm, placed it in a very vulnerable position. The recent legal recognition of sovereign rights claims and intellectual property protection over genetic resources add to the seriousness of this situation. However, with the exception of plant breeders, the importance of this potential contribution is not appreciated at most levels and in the majority of related disciplines.

The lack of recognition of the importance of genetic resources has relegated them to a position of low financial priority in South Africa. Consequently the necessary human and technical resources are poorly developed. Awareness of the role of genetic resources is somewhat more advanced in the rest of the region and an inventory of the genetic resources personnel and infrastructure within the region, should be developed.

Within and between the few *ad hoc* genetic resources initiatives in South Africa there is a lack of coordination and a cogent policy. Because genetic resources are such a multidisciplinary and multidimensional field, its successful implementation requires the input of and collaboration with other major disciplines. These include, *inter alia*, taxonomy, conservation, monitoring programmes (especially those dealing with endangered species), database management, training and education, agriculture, horticulture, forestry, tourism and ethnobotany. At present these links do not exist within South or southern Africa.

Largely due to a lack of appreciation of the value of South Africa's genetic resources, indigenous germ plasm leaves the country on a regular basis with few restrictions. It is frequently used to the financial advantage of the importers, with no financial benefits accruing to South Africa. In addition, an unspecified amount of South Africa's genetic diversity is scattered around the world in botanical gardens, crop breeding programmes and horticultural initiatives. Many of the original genotypes or even species in use in these programmes are probably no longer available in South Africa. This material needs to be inventoried and attempts have to be made to retrieve duplicate samples for the country's own conservation programme.

PLAN OF ACTION REQUIRED TO ATTAIN GOALS

1. National strategy

The Working Group recommended that a national forum be convened in South Africa to develop a national programme similar to those in other SADC countries. The meeting would include conservation researchers, land-use managers, users of genetic resources and policy makers, to make recommendations on a plant genetic resources strategy and on a technical advisory committee (TAC). Based on the recommendations of the forum, the TAC would formulate guidelines on national strategy, including:

- National plant genetic resources programmes.
- Priorities.
- Methodology.
- Responsibilities.
- Coordination.
- Legal requirements.
- Policy and legislation.
- Commercialization and marketing.
- Training.

2. Legislation

Recognizing the considerable value of genetic resources of the country and of the region, we consider it imperative that appropriate legislation be drafted and enacted at the earliest opportunity to protect this material as well as to safeguard rights over it where appropriate. This legislation must be applicable to all plant diversity in the country and should aim at standardization throughout the region in order to strengthen the concept of regional cooperation in matters concerning genetic resources. International patent attorneys and environmental lawyers will have to be involved in this process.

It is of fundamental importance that this legislation in no way restricts access to this material by user groups, but aims to ensure appropriate compensation and financial returns should it become commercially utilized in its original state or altered form.

This controlled open-door policy must aim at encouraging international exchange and collaboration. Unless carefully worded and applied, it could have the opposite effect to that intended, with potentially serious consequences.

If the system outlined above is to function effectively, all requests for the collection of germ plasm by foreign institutions or individuals must be channelled through one central body in South Africa, preferably the technical advisory committee of the national plant genetic resources programme. In this way the TAC will be able to:

- Keep records of all material leaving the country.
- Note the foreign institutions and countries involved.
- Identify suitable local institutions for collaborative ventures.
- Ensure that the appropriate legal contract accompanies all exported indigenous material.
- Pursue issues pertaining to royalties or profit-sharing agreements where appropriate.

Consideration should be given to adopting the proposed Code of Conduct for the collection and transfer of plant resources, as drawn up by the FAO Commission on Plant Genetic Resources.

3. Training and education

Specialized training needs are evident in the fields of:

- Gene bank curation and maintenance.
- Storage of recalcitrant material.
- Conservation of genetic diversity in botanical gardens, arboreta and field gene banks.

- Germ plasm collecting methods, especially those aimed at sampling maximum genetic diversity.
- Evaluation and characterization.
- Multiplication and regeneration.
- Seed technology for gene banks.

At present there are few or no staff trained in most of these disciplines in South Africa. However, the country already has considerable expertise and infrastructure in closely allied disciplines such as plant breeding, seed physiology and taxonomy. Training is also required at tertiary and postgraduate level. All tertiary institutions offering courses in botany, horticulture and nature conservation should be approached to include relevant components of genetic resources theory and practice in their curricula. Collaboration should be sought with relevant organizations in arranging and providing training opportunities within the region or elsewhere, as appropriate.

Public awareness of plant genetic resources issues should be increased by, *inter alia*, establishing close links with educational and environmental organizations.

4. National and international links

Close links must be established between groups such as herbarium curators and horticulturists, in order to rationalize some of the practical and logistical aspects of the programme such as collecting and multiplication. This will ensure more efficient use of funds and other resources for *ex situ* conservation.

A concerted and immediate effort should be made to foster close ties with all the major international genetic resources initiatives and programmes, as well as with other national and regional programmes elsewhere in the world.

5. Active marketing of genetic resources

Due attention has not been given to this aspect, but it is felt that the conservation of genetic resources will be really successful only if markets and users are found for this resource. These markets will be largely, but not exclusively, international. It is suggested that a professional marketing person rather than a botanist be responsible for this aspect.

CONCLUSION

The Working Group felt that *ex situ* conservation in no way competes with *in situ* conservation, but should be viewed as a complementary activity which underwrites *in situ* conservation. Only by the carefully considered tandem use of

both these conservation methods will a comprehensive national genetic resources conservation programme be possible in South Africa.

Genetic resources have an important role to play in biodiversity conservation and in food security. The priorities are determined by real human needs, which should provide a strong incentive for a flow of funds to support this activity.

Plant genetic resources activities are an essential and integral component of the sustainable economic exploitation of the region's biodiversity. In addition, they have the potential to provide the vital economic interface with the commercial world for the generation of funds for the continued *in* and *ex situ* conservation of this globally important resource.

WORKING GROUP 10

ETHNOBOTANY AND TRADITIONAL MEDICINE

CONVENER: Tony Cunningham

PARTICIPANTS: Meryl Abrahams, Sizwe Cawe, John Cooke, C. Cupido, Donald Grierson, Louise Hansen, Vanessa Hendriks, Anne Hutchings, Charles Kadzere, Ram Kapooria, Edward Mabogo, O. Makunga, Jenny Mander, G. Matsabisa, Steve Mavi, Martin Mbewe, Asdiela Moerat, Kingston Nyamapfene, Maxwell Poswal, Gill Scott, A. Sulaiman, Saskia Oosterhout, Hannelie Winterbach

INTRODUCTION

Indigenous plant use, in particular ethnobotany and traditional medicine, is a very topical field but has been hampered by limited communication, inadequate cross-cultural/interdisciplinary methodologies and the need for a theoretical framework. There is a strongly developed national programme in South Africa but weak regional linkages. The Working Group identified the following general goal for southern Africa:

To promote the cultural, social, economic and scientific benefits to be derived by people from the sustainable use and conservation of the southern African flora.

ACTIVITIES TO ACHIEVE THE GOAL

The Working Group identified five priorities for action:

1. Improve communication. Linkages must be formed between researchers, resource managers and users through regional networking and interchange of experience and information by:
   - Developing an interactive newsletter.
   - Extending activities from national to regional programmes.
   - Initiating collaborative research on a regional basis.
   - Convening Working Group meetings at least every two years.
   - Developing a directory of who is doing what and where—building on the existing FRD/Indigenous Plant Use Programme directory.

2. Inventories, syntheses and reviews of existing knowledge, including:

    - Pharmacopoeia for southern Africa.
    - Database on edible species and nutritional values.
    - Analysis of species with horticultural potential—what is being sold already, where, size of market, new introductions?
    - Crop/pastures/forage—what is the level of indigenous plant use in these fields?

3. Identify gaps and develop regional centres of excellence/expertise for teaching and research, especially in the following geographic or disciplinary areas:

    - Arid zone (especially Namibia).
    - Savanna (Botswana and Zimbabwe).
    - High population density areas; high endemism centres (western Cape, Natal).
    - Such centres of excellence should develop a strong theoretical framework and link with herbaria development and field surveys.

Cautionary note: there should not be a concentration of funding in only one area.

4. Coordination and design of curricula to include greater emphasis on indigenous plant use, at:

    - Schools (primary to secondary).
    - Undergraduate/technical courses.
    - Postgraduate studies.

5. Relevant user-driven research agenda for the long-term benefit of people and conservation. This should be achieved by adopting and developing new methodologies through consultative and participatory approaches to:

    - Influence policy and policy makers by communicating the role of indigenous plant use, especially in development and economics.
    - Link with conservation, agricultural and forestry programmes and appropriate technology to develop alternatives to overexploited resources.
    - Maximize regional economic benefits and add value to production systems by including the use of southern African flora.

ISSUES: SOCIAL, BIOLOGICAL AND ECONOMIC

1. Social issues

A wide diversity of social issues were identified as influencing the availability and sustained use of indigenous plants in southern Africa, namely:

- Urbanization.
- Land reform.
- Increasing demand and diminishing resources.
- Cultural changes.
- Loss of traditional knowledge.
- Loss of species.
- Change in resource base.
- Access to and control of resources.
- Commercialization.
- Urban-biased policy on development.
- Economics, both macro- and micro- and the policies affecting these.
- Unemployment and the resulting impacts on indigenous plant use.

2. Biological issues

Three priorities for action were considered—the need for taxon-based studies, an arid-zone emphasis and more attention to population biology.

Taxonomic or use categories

Research and development on indigenous plants should be focused on species falling within the following categories:

- Medicinal (e.g. Apocynaceae, Lamiaceae, Rubiaceae and Euphorbiaceae).
- Edibles (e.g. Sapotaceae, Anacardiaceae, Rubiaceae, Fabaceae).
- Horticultural (e.g. Iridaceae, Orchidaceae, Liliaceae).
- Crop-related and forage species (e.g. Fabaceae, Cucurbitaceae, Poaceae).
- Craftwork (e.g. Arecaceae, Juncaceae, Flagellariaceae).
- Agroforestry (e.g. Fabaceae, Asteraceae).

There is a need to link species-specific studies to regional database/mapping exercises to identify priority areas in terms of centres of diversity and endemism.

Need for an arid-zone perspective

The arid zone is currently underresearched in terms of indigenous plant use. For example, the potential for horticulture (e.g. *Pachypodium*, *Lithops*) and new crops for marginal lands must be assessed.

Population biology perspective

Another topic that needs inclusion in the agenda for indigenous plant use studies is information on the biology of each species, in terms of life form, ecosystem dynamics, recruitment, biomass production, etc.

3. Economic issues

The most critical and urgent issue relating to the economic exploitation of southern African botanical resources is the need for national and regional protocols for the protection of intellectual property rights. This matter will be of great significance to the implementation of the Convention on Biological Diversity and should enjoy high priority. Other important economic issues include:

Sustainable consumption of:

- Medicinal plants (for humans and animals), food plants, crafts (weaving, carving), fuelwood, building material, traditional dress, dyes, fish poisons.
- New uses/international trade: devil's claw (*Harpagophytum*), marula, cut flowers, essential oils, gum arabic.

One-off collections for development—biodiversity prospecting for:

- Industry: drugs, pesticides, herbicides, resins, waxes, perfumes.
- Horticulture: bulb trade, new fruit crops (e.g. marula), *Rumohra* fern.
- Crop plant/forage/pasture/grasses.

Nonconsumptive use:

Tourism, especially ecotourism, is one of the fastest growing industries globally. Southern Africa has an as yet untapped resource in plant-based ecotourism, most especially in the spectacular flora of the Cape Floristic Region.

Participants' addresses

Ms Meryl Abrahams, Pharmacology Department, University of Cape Town, Medical School, Observatory, 7925 South Africa.

Mr Avi Anati, Ministry of Science and Technology, P.O. Box 18195, Jerusalem, 91181, Israel.

Ms Fiona Archer, Department of Botany, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Mrs Robyn Arnold, c/o National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Mr Trevor Arnold, National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Ms Liz Ashton, Cape Town City Council, P.O. Box 1694, Cape Town, 8000 South Africa.

Dr Snowy Baijnath, University of Durban-Westville, P.O. Box X54001, Durban, 4000 South Africa.

Miss Jaana Ball, Botany Department, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Dr Kevin Balkwill, Department of Botany, University of the Witwatersrand, Private Bag X3, Wits, 2050 South Africa.

Ms Mandy Balkwill, Department of Botany, University of the Witwatersrand, Private Bag X3, Wits, 2050 South Africa.

Dr Salomao Bandeira, Eduardo Mondlane University, P.O. Box 257, Maputo, Mozambique.

Mr Nigel P. Barker, Botany Department, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Mrs Ann Bean, Bolus Herbarium, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Ms Aleka Beaumont, Botanical Society of South Africa, Kirstenbosch, Claremont, 7735 South Africa.

Mr Grant Benn, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Mr Chris Berens, Protea Atlas Project, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Mr Hugo Bezuidenhout, National Parks Board, P.O. Box 110040, Hadisonpark, Kimberley, 8306 South Africa.

Mr Ashish Bodasing, TRAFFIC East/Southern Africa, Private Bag X11, Parkview, 2122 South Africa.

Dr John Bolton, Botany Department, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Prof. William J. Bond, Botany Department, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Ms A.J.N. Bosa, Botany Department, University of Transkei, Private Bag X1, UMTATA, 5100 South Africa.

Dr Daan J. Botha, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr Wayne B. Boyd, Nature and Environmental Conservation, P.O. Box 1232, Nelspruit, 1200 South Africa.

Ms Kate Braun, Swaziland National Trust Commission, Malolotja Nature Reserve, P.O. Box 1797, Mbabane, Swaziland.

Dr Neville Brown, Conservation Biology, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr John E. Burrows, Buffelskloof Private Nature Reserve, P.O. Box 710, Lydenburg, 1120 South Africa.

Mrs S. Burrows, Buffelskloof Private Nature Reserve, P.O. Box 710, Lydenburg, 1120 South Africa.

Dr C.M. Cameron, Director General, Department of Environment Affairs, Private Bag X447, Pretoria, 0001 South Africa.

Mr Sizwe Cawe, Botany Department, University of Transkei, Private Bag X1, Umtata, 5100 South Africa.

Mr Augustine Chikuni, National Herbarium & Botanic Garden, P.O. Box 528, Zomba, Malawi.

Ms Elise Cloete, Herbarium, Department of Botany, University of Transkei, Private Bag X1, Umtata, 5100 South Africa.

Dr Michael Cohen, Cape Nature Conservation, Port Elizabeth, 6001 South Africa.

Prof. John A. Cooke, Department of Biology, University of Natal, Durban, 4001 South Africa.

Mr Fernando Costa, Monte das Quintas, Santo Amaro, 4770, Sousel, Portugal.

Prof. Richard M. Cowling, Institute for Plant Conservation, Botany Department, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Dr Tim Crowe, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Dr Tony Cunningham, WWF/UNESCO/Kew People and Plants Initiative, 84 Watkins Street, White Gum Valley, Fremantle, 6162, Western Australia.

Mr C.N. Cupido, Department of Plant Sciences, University of Fort Hare, Private Bag X1314, Alice, 5700 South Africa.

Dr George Davis, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Ms Helen de Klerk, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Dr John Donaldson, Conservation Biology, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr Bob Drummond, National Herbarium, P.O. Box 8100, Causeway, Harare, Zimbabwe.

Ms Agostinho Duarte, Science Faculty, Agostinho Neto University, Luanda, Angola.

Dr Roger P. Ellis, Agricultural Research Council, Private Bag X05, Lynn East, 0039 South Africa.

Prof. Kobus Eloff, Private Bag X101, Pretoria, 0001 South Africa.

Mr Russel Engelke, Horticulture Department, University of Natal, Pietermaritzburg, 3201 South Africa.

Ms Cornelia A. Erasmus, Environmental Section, Route MA76, Private Bag X152, Pretoria, 0001 South Africa.

Mr Matt J. Erasmus, Agricultural Research Council, Private Bag X05, Lynn East, 0039 South Africa.

Dr David Everard, Division of Forest Science & Technology, CSIR, P.O. Box 395, Pretoria, 0001 South Africa.

Mr U. Feiter, P.O. Box 200, Winterton, 3340 South Africa.

Mr Antony A. Ferrar, 21 Rockridge Road, Parktown, 2193 South Africa.

Mrs Lyn Fish, National Herbarium, Private Bag X101, Pretoria, 0001 South Africa.

Mrs L. Fraser, 181 MalPark, 24 Prospect Hall Road, Durban North, 4051 South Africa.

Mrs Caroline Gelderblom, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Dr C.J. Geldenhuys, Division of Forest Science & Technology, CSIR, P.O. Box 395, 0001 Pretoria.

Dr Peter Goodman, Natal Parks Board, Mkuzi Game Reserve, Private Bag X550, Mkuzi, 3965 South Africa.

Ms Margaret Graca, Science Faculty, Agostinho Neto University, Luanda, Angola.

Prof. E.H. Graven, P.O. Box 16, Gouda, 6821 South Africa.

Mr D.S. Grierson, Plant Sciences, University of Fort Hare, Private Bag X1314, Alice, 5700 South Africa.

Ms Pippa Haarhof, South African Museum, Cape Town, 8001 South Africa.

Prof. Anthony Hall, Bolus Herbarium, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Ms Louise Hansen, Foundation for Research Development, P.O. Box 2600, Pretoria, 0001 South Africa.

Dr Inga Hedberg, Uppsala University, P.O. Box 541, S-751 21 Uppsala, Sweden.

Prof. Olaf Hedberg, Uppsala University, P.O. Box 541, S-751 21 Uppsala, Sweden.

Ms Vanessa Hendriks, Botany Department, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Mr Barry Heydenrych, Botanical Society of South Africa, Kirstenbosch, Claremont, 7735 South Africa.

Mr Craig Hilton-Taylor, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Ms Saskia Hobson, National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Dr Tim Hoffman, Stress Ecology, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Prof Brian J. Huntley, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mrs Anne Hutchings, Department of Botany, University of Zululand, Private Bag X1001, Kwadlangezwa, 3886 South Africa.

Mr S. Iourine, University of Natal, P.O. Box 375, Pietermaritzburg, 4001 South Africa.

Ms S. Izidine, National Institute of Agronomic Research, P.O. Box 3658, Maputo, Mozambique.

Mr James Jackelman, City Engineer's Department, P.O. Box 1694, Cape Town, 8000 South Africa.

Ms Mariaan Jooste, Agricultural Research Council, Private Bag X05, Lynn East, 0039 South Africa.

Prof. Charles T. Kadzere, Department of Livestock and Pasture Sciences, University of Fort Hare, Private Bag X1314, Alice, 5700 South Africa.

Mr Henry Kamau, c/o ILRAD, P.O. Box 30709, Nairobi, Kenya.

Prof. Ram G. Kapooria, Department of Biology, University of Zambia, P.O. Box 32379, 10101 Lusaka, Zambia.

Miss Marinda Koekemoer, National Herbarium, National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Mr At Kruger, Agricultural Research Council, Private Bag X05, Lynn East, 0039 South Africa.

Dr Hubert Kurzweil, National Botanical Institute, Compton Herbarium, Private Bag X7, Claremont, 7735 South Africa.

Ms Annelise le Roux, Jonkershoek Nature Conservation Station, Private Bag X5014, Stellenbosch, 7599 South Africa.

Mr Gillian Lewis, Botany Department, Rhodes University, P.O. Box 94, Grahamstown, 6140 South Africa.

Dr Peter Linder, Botany Department, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Dr Gail Littlejohn, ARC-VOPI, Private Bag, Elsenburg, 7607 South Africa.

Ms P. Lorber, Bolus Herbarium, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Dr Mandy Lombard, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Mr A. Barrie Low, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Prof. Roy A. Lubke, Department of Plant Sciences, Rhodes University, P.O. Box 94, Grahamstown, 6140 South Africa.

Dr D.E.N. Mabogo, Department of Botany, University of Venda, Private Bag X5050, Thohoyando, South Africa.

Dr Ian Macdonald, SANF, P.O. Box 456, Stellenbosch, 7599 South Africa.

Miss Gillian Maggs, National Botanical Research Institute, Private Bag 13184, Windhoek 9000, Namibia.

Mr O. Makunga, Department of Plant Sciences, University of Fort Hare, Private Bag X1314, Alice, 5700 South Africa.

Mrs Jenny Mander, Institute of Natural Resources, P.O. Box 375, Pietermaritzburg, 3200 South Africa.

Mr G. Maneveldt, Department of Botany, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Dr John Manning, Compton Herbarium, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Dr Peta Masson, Busutu Pulp Company, Private Bag, Mbabane, Swaziland.

Dr Liz Matos, Science Faculty, Agostinho Neto University, C.P. 815, Luanda, Angola.

Dr Joseph Z.Z. Matowanyika, IUCN Regional Office for Southern Africa, P.O. Box 745, Belgravia, Harare, Zimbabwe.

Mr G. Matsabisa, Department of Pharmacology, University of Cape Town, Rondebosch, 7700 South Africa.

Mr Stephen Mavi, National Herbarium, P.O. Box 8100, Causeway, Harare, Zimbabwe.

Mr Martin Mbewe, Thusano Lefatsheng, Private Bag 00251, Gaborone, Botswana.

Mr Andrew Mbiru, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Mr Dave J. McDonald, National Botanical Institute, Conservation Biology, Private Bag X7, Claremont, 7735 South Africa.

Mr Steve G. McKean, Natal Parks Board, P.O. Box 662, Pietermaritzburg, 3200 South Africa.

Prof. Bruce McKenzie, Department of Botany, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Dr Tracy McLellan, Botany Department, Private Bag X1, Umtata, 5001 South Africa.

Mr Walter E. Menne, Zululand Environmental Alliance, P.O. Box 421, Kwa-Mbonambi, 3915 South Africa.

Dr Jolanta Mesjasz-Przybylowicz, Department of Botany, University of the Witwatersrand, Private Bag 3, Wits, 2050 South Africa.

Mr J. Meyer, National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Mr Walter Middelmann, 13 Lady Anne Ave, Newlands, 7700 South Africa.

Mr Guy F. Midgley, Stress Ecology, National Botanical Institute, Private Bag X16, Rhodesgift, 7707 South Africa.

Mr F. Mitchell, Department of Botany, University of Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Ms Aadiela Moerat, Botany Department, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Ms Helen Moss, Roodeplaat Grassland Institute, Private Bag X05, Lynn East, 0039 South Africa.

Mrs Mahlape Mothepu, LHDA, P.O. Box 7332, Maseru 100, Lesotho.

Mr Paulino Munisse, National Institute of Agronomic Research, P.O. Box 3658, Maputo, Mozambique.

Mr John Muriuki, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Private Bag X7, Rondebosch, 7700 South Africa.

Dr Norman Myers, Upper Meadow, Old Road, Headington, Oxford 8X3 8SZ, United Kingdom.

Mr James Nair, Department of Chemistry, University of Natal, Durban, 4001 South Africa.

Ms Ingrid Nanni, Conservation Biology, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Dr Nouhou Ndam, Limbe Botanic Garden, P.O. Box 437, Limbe, Cameroon.

Mr Alfred Ngwenya, Natal Herbarium, Botanic Gardens Road, Durban, 4001 South Africa.

Mr Geoffrey R. Nichols, Durban Parks Department, Durban Municipality, P.O. Box 3740, Durban, 4000 South Africa.

Prof. Steven Njuguna, IUCN Regional Office Eastern Africa, P.O. Box 68200, Nairobi, Kenya.

Prof. Bertil Nordenstam, Swedish Museum of Natural History, Box 50007, S-104 05 Stockholm, Sweden.

Prof. Kingston Nyamapfene, Department of Agronomy, Faculty of Agriculture, University of Fort Hare, Alice, 5700 South Africa.

Mr Ted Oliver, Stellenbosch Herbarium, P.O. Box 471, Stellenbosch, 7599 South Africa.

Mr Anthony Palmer, Department of Botany, Rhodes University, Grahamstown, 6140 South Africa.

Dr Colin Paterson-Jones, 37 Orchard Road, Newlands, 7700 South Africa.

Dr Dee A. Paterson-Jones, Compton Herbarium, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr N. Parker, Computer Services, University of Transkei, Private Bag X1, Umtata, 5100 South Africa.

Dr Peter Phillipson, Department of Botany, Rhodes University, P.O. Box 94, Grahamstown, 6140 South Africa.

Dr Shirley M. Pierce-Cowling, Botany Department, University of Cape Town, Rondebosch, 7700 South Africa.

Prof. Maxwell A.T. Poswal, Department of Agronomy, University of Fort Hare, Private Bag X1314, Alice, 5700 South Africa.

Dr Tony Rebelo, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Ms Yvonne Reynolds, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Ms S. Roberts, Department of Chemistry, University of Natal, Durban, 4001 South Africa.

Dr John Rourke, Compton Herbarium, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr Koos Roux, Compton Herbarium, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr C. Ruiters, Botany Department, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Dr Mike Rutherford, Stress Ecology, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mrs Gillian Scott, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mr Rob Scott-Shaw, Natal Parks Board, P.O. Box 662, Pietermaritzburg, 3200 South Africa.

Mr André Share, Botany Department, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Ms Stella Simuyu, National Museums of Kenya, P.O. Box 45661, Nairobi, Kenya.

Ms Renette Smit, Department of Botany, University of Pretoria, Pretoria, 0001 South Africa.

Mr Brad Smith, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Dr Gideon Smith, National Herbarium, Private Bag X101, Pretoria, 0001 South Africa.

Ms Rowena Smuts, Botany Department, University of Cape Town, Private Bag X7, Rondebosch, 7700 South Africa.

Mr Tami Sokutu, Botany Department, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Mr Jonathan Spencer Jones, P.O. Box 398, Cape Town, 8000 South Africa.

Ms Diane Stafford, National Botanical Institute, Private Bag X17, Rondebosch, 7735 South Africa.

Mrs R. Stanvliet, Cape Nature Conservation, Stellenbosch, 7599 South Africa.

Prof. Charles Stirton, Royal Botanical Gardens, Kew, Richmond, Surrey TW9 3AB, United Kingdom.

Ms Wendy Strahm, Species Survival Programme, Rue Mauverney 28, CH 1196 Gland, Switzerland.

Prof. Arne Strid, Botanical Laboratory, University of Copenhagen, 140-Gothersgade, DK-1123 Copenhagen K, Denmark.

Ms A. Sulaiman, Department of Botany, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Dr Sumitra Talukdar, National University of Lesotho, P.O. Roma, 180, Lesotho.

Mr Jonathan Timberlake, Chesa Research Station, P.O. Box 467, Bulawayo, Zimbabwe.

Mr Terry H. Trinder-Smith, Bolus Herbarium, University of Cape Town, Private Bag, Rondebosch, 7700 South Africa.

Mr Kim Tucker, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Mr Alexander Valentine, Department of Botany, University of the Western Cape, Bellville, 7535 South Africa.

Miss Francine van Heerden, National Parks Board, Private Bag X6528, George, 6530 South Africa.

Mrs Ina van der Linde, Vrye Weekblad, P.O. Box 73878, Lynnwood Ridge, Pretoria, 0040 South Africa.

Miss Saskia van Oosterhout, Ministry of Agriculture, P.O. Box 8108, Causeway,, Harare, Zimbabwe.

Prof. Johannes van Staden, Botany Department, University of Natal, P.O. Box 375, Pietermaritzburg, 3200 South Africa.

Ms Mariana van Wyk, National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Mrs Lindi van Rooyen, P.O. Box 13501, Sinoville, 0129 South Africa.

Mr Wynand van Rooyen, P.O. Box 13501, Sinoville, 0129 South Africa.

Ms Janine Victor, National Botanical Institute, Private Bag X101, Pretoria, 0001 South Africa.

Mr Maritz Wahl, Department of Environment Affairs, Private Bag X447, Pretoria, 0001 South Africa.

Dr R. Danny Walmsley, Environmental Programmes, Foundation for Research Development, P.O. Box 2600, Pretoria, 0001 South Africa.

Ms Stephanie Wand, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

Mrs Deryl Weilbach, Department of Environment Affairs, Private Bag X447, Pretoria, 0001 South Africa.

Mr Frans Weitz, Department of Botany, University of the Western Cape, Private Bag X17, Bellville, 7535 South Africa.

Ms Rosemary Williams, Natal Herbarium, National Botanical Institute, Botanic Gardens Road, Durban, 4001 South Africa.

Mr Chris Willis, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Ms Hannelie Winterbach, Nature and Environmental Conservation, P.O. Box 517, Bloemfontein, 9300 South Africa.

Mr Arné Witt, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700 South Africa.

Ms Julia Wood, National Botanical Institute, Private Bag X7, Claremont, 7735 South Africa.

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